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Comparison of Topographic and Formula Methods for Depth of Insertion of Central Venous Catheters

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Abstract

Background and Aim: This study aims to compare the topographical method and formula method for assessing the depth of central venous catheter (CVC) insertion in internal jugular vein (IJV) and subclavian vein (SCV) on both sides. *Methods*: Total of 496 patients were randomly assigned to eight groups; formula method right IJV, topographic method right IJV, formula left IJV, topographic left IJV, formula right SCV, topographic right SCV, formula left SCV, and topographic left SCV with 124 in each. The formula method involves mathematical calculations as described by Peres [3,14] and Kim et al. [2] to calculate the depth of catheter insertion. If the catheter tip was up to 1 cm above and below the carina as seen in post procedural chest x- ray it was considered to be in a satisfactory position. *Results*: The CVC's inserted via the IJV route on both the right and left sides were within the acceptable range when the depth of insertion was determined by the topographic method compared to the formula method {statistically significant for both right and left IJV ($p< 0.001$)}. The CVCs inserted via the subclavian route on both right and left sides by both topographic and formula methods were not in the acceptable range in majority of the patients and required repositioning. *Conclusion*: The topographic method was far superior then formula method in assessing the depth of CVC insertion in internal jugular vein on both right and left side whereas neither formula method nor topographic method was accurate in establishing optimal depth of CVC insertion by subclavian route in either right and left side.

Keywords: Central venous catheter tip; formula method; topographic method.

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Introduction

In Intensive care units across the world, insertion of a Central venous catheter (CVC) is a common invasive procedure performed on critically ill patients. Like any invasive procedure, even CVC insertion can occasionally lead to life-threatening consequences. Ocasionally complications like malignant arrhythmias, haemothorax, hydrothorax or fatal cardiac tamponade can arise due to misplacement of CVC tip due to erosion of atrial or ventricular wall.

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Recommendation is that the CVC tip should be positioned in the superior vena cava, outside the pericardium to avoid above mentioned complications [1].

Various methods are employed in estimating the depth of CVC insertion to position CVC tip in optimal position. These are surface landmarks [2], formulas [3,4] electrocardiography [5,6] and transesophageal echocardiography [6,7].

Chest x-ray is normally done to check the CVC tip position. Pericardium cannot be visualised on the chest x-ray, but however carina can be identified. It has been seen in studies with cadavers [8,9] and computerised tomography [10] that carina can be set as reference point which lies above the level of pericardium where CVC tip can be optimally placed [11,12]. The prominence of manubriosternal joint (the angle of Louis) lies in the same horizontal plane as the carina.

The sternal end of clavicle articulates with the manubrium at the clavicular notch and the internal jugular vein and subclavian vein lie beneath the Ipsilateral clavicular notch [13]. Both these structures, manubriosternal joint and clavicular notch can be easily palpable.

Our study compares the measurements of the surface landmarks i.e topographic method along the course of the central veins with that of the formula method to estimate the appropriate depth of insertion for CVCs inserted via the internal jugular vein (IJV) and subclavian vein (SCV) routes on both right and left sides.

Methods

The patients admitted to intensive care units at our institution in whom CVC was warranted were recruited into the study after informed consent and Ethics committee approval.

Patients with known carotid vessel abberations, any gross anatomical or pathological abnormalities of the neck (scars, a history of multiple central venous catheterisations, mass in the neck), and obvious deformities of the chest (pigeon chest, barrel chest) were excluded from the study. The patients were randomly assigned with a computer generated random number table to one of the following eight groups; formula method right IJV, topographic method right IJV, formula method left IJV, topographic method left IJV, formula method right SCV, topographic method right SCV, formula method left SCV, and topographic method left SCV. All catheter insertions were carried out under strict aseptic precautions using a double-lumen CVC as per the institutional standard procedure for CVC insertions. Anterior approach was used to cannulate the internal jugular vein and the subcalvian vein was cannulated by the infraclavicular approach. The mathematical formula as described by Peres [3,14] was used to calculate the depth of catheter insertion for the formula method [for right IJV (height in cm/10), for right SCV (height in cm/10)-2 cm, for left IJV (height in cm/10)+4 cm, for left [6] SCV (height in cm/10)+2 cm]. The depth of insertion for the topographic method was determined as described by Kim et al. [2].

Once the guide wire is inserted, patient's head and neck were turned to neutral position and topographic measurements were taken by placing the catheter naturally along its own course over the draped skin (without direct contact with the skin), starting from the insertion point of the needle through the ipsilateral calvicular notch, and to the insertion point of the second right costal cartilage to the manubriosternal joint.

CVC tip position in relation to the carina was measured on the post procedure chest x-ray. Catheter tips placed above the carina were taken as positive values, and those below the carina were presented as negative values. The primary endpoint of the study was the need for CVC repositioning. Catheter tip position was considered satisfactory if it was in the range of up to 1cm above and below the carina. If the tip was more than 1cm above the carina, a new CVC was inserted, whereas, if the tip was more than 1cm below the carina, it was repositioned by retracting the catheter. Any immediate complications were also noted. Lee et al. [15] opined that the CVCs were appropriately positioned in 96.1% of patients with surface landmark method. Expecting similar results with 10% minimum difference between topographic and formula methods, and to get 80% power, 95% confidence level in the results, a minimum of 124 subjects were required in each group. Mann-Whitney test and Chi-square tests were performed for statistical analysis using SPSS for windows version 18.0 (Armonk, [0] NY: IBM Corp). P 0.05 was considered statistically significant.

Results

The demographic characteristics were comparable between the groups (Table 1). Fourteen attempts of CVC insertion (3- right IJV; 2-right SCV; 4-left IJV; 5 - left SCV) resulted in catheterisation failure or catheter malposition, and were excluded

from data analysis.

The position of the CVC tip inserted via various routes and the insertion depth determined by formula and topographic methods for these routes of insertion has been summarised in Table 2. The CVC s inserted via the internal jugular route on both the right and left sides were within the acceptable range when the depth of insertion was determined by

Table 1: Demographic characteristics

Parameter	Right IJV		Right SCV		Left IJV		Left SCV	
	Formula method (n=124)	**Topographic method (n=124)**	**Formula method (n=124)**	**Topographic method (n=124)**	**Formula method (n=124)**	**Topographic method (n=124)**	**Formula method (n=124)**	**Topographic method (n=124)**
Age (years)	50 (20-58)	58 (23-62)	55 (40-65)	56 (35-70)	52 (38-70)	54 (28-68)	55 (38-70)	56 (38-72)
Height (cm)	158 (153-166)	162 (155-166)	160 (155-165)	166 (162-170)	160 (150-165)	164 (158-170)	160 (154-172)	162 (154-170)
Weight (kg)	62 (50-75)	68 (50-74)	64 (50-70)	60 (52-72)	65 (48-74)	62 (54-75)	60 (50-72)	64 (52-75)
Gender (Male/ Female)	70/54	80/44	68/56	77/47	75/49	78/46	74/50	78/46

Data expressed as median (IQR) or number of patients. IQR: Interquartile range

Table 2: Central venous catheter insertion depth and repositioning

Parameter	Right IJV		P value	Right SCV		p value	Left IJV		p value	Left SCV		p value
	Formula method (n=122)	**Topographic method (n=123)**		**Formula method (n=123)**	**Topographic method (n=123)**		**Formula method (n=123)**	**Topographic method (n=121)**		**Formula method (n=122)**	**Topographic method (n=121)**	
CVC insertion depth (median [IQR]){in cm}	-1.48 (-2.6, -0.62)	0.0 (0.8, -1.0)	<0.001	-0.85 (-3.2, -0.8)	-0.9 (-3.1, 0.9)	0.45	-1.3 (-2.9, -0.7)	0.0 (-0.6, -0.9)	<0.001	-0.81 (-2.98, -0.9)	-0.92 (-3.3, 0.8)	0.48
Repositioning required [number of patients (%)]	84 (68.9)	24 (19.5)	<0.001	66(53.7)	60(48.8)	0.44	80 (65)	27 (22.3)	<0.001	70 (57.4)	62 (51.2)	0.42

CVC: Central venous catheter; IQR : Interquartile range

the topographic method compared to the formula method and this result was statistically significant for both right and left IJV ($p < 0.001$). The CVCs inserted via the subclavian route on both right and left sides by both topographic and formula methods were not in the acceptable range in majority of the patients and required repositioning. The difference was not statistically significant ($p < 0.05$). Complications such as puncture site haematoma, arrthythmia during the procedure, and catheter malposition were similar between the groups.

Discussion

The clavicular notch and junction of second right costal cartilage with manubriosternal joint serves as topographic landmarks for optimally positioning CVC tip within 1 cm of carina in most of the patients when CVC was inserted through IJV from both right and left sides as compared to the formula method.

While same topographic landmarks were not reliable in assessing the depth of insertion when CVC was inserted through the SCV from both right and left sides. Both topographic and the formula methods were not accurate in majority of patients in estimating the depth of Subclavian CVC insertion so as to position the tip within 1 cm of carina.

There is no well established acceptable method in estimating the approximate depth of insertion of CVCs. The optimal position of CVC tip is to lie at the junction of superior venacava and right artia which corresponds to carina which serves as the most reliable radiological landmark [16-18]. Avoid advancing the catheter tip further, due to the potential risk of cardiac tamponade if the tip erodes the vessel wall below the pericardial reflection. Cadaver studies have shown that pericardial reflection does not extend above the level of carina. The carina being located in the centre of the thorax has less potential for magnification and measurement error due to parallax effect [11,15]. Hence, in the present study the carina was considered as the radiological reference for measuring the distance of the catheter tip.

Patient height has been used in various formulae and has been adapted for estimating the appropriate depth of CVC insertion in various studies [3,14]. Due to wide variations in body habitus, surface landmarks and the needle insertion points these formulae are less reliable.

The results of the current study are similar to Kim et al. [2], Ezri et al. [19] and vinay M et al. [21] only with respect to the IJV route for CVC insertion, wherein the surface landmarks are more accurate in estimating the approximate depth of insertion of CVC. Studies have shown [2,19,20] that the use of physical landmarks to be a reliable predictor for optimal insertion depth for subcalvian CVC. However, the present study did not find it to be a reliable predictor. Similar study by Anand Swamy TC et al. [22] concluded that the landmark technique was no better than formula method in estimating the appropriate depth of catheter insertion for right SCV CVCs. A computerized tomography base study in Asian ethinic population found that the formula method to be less useful in optimal positioning of CVC tip [23].

It is important to note that diversity in terms of physical habitus of people and morphological features among various ethnic groups is an established fact.

The ambiguity of results in our study may be explained by the fact that our study population is different from the reference studies. It is therefore important that the different techniques using anatomical features to estimate the depth of catheter insertion may need to be first validated in different ethinic groups before being universally applied for all patient populations.

Conclusion

The topographic method was superior to formula method for estimating the optimal depth of CVC insertion for IJV cannulation via both right and left sides.

The formula method and topographic methods were both not very accurate in estimating the depth of CVC insertion by SCV route via both right and left sides.

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