



## ORIGINAL ARTICLE

# Assessment of Central Venous Catheterization Using Electrocardiographic versus Landmark Techniques in Pediatrics Undergoing Open Heart Surgery; Which Technique is Superior?

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## ABSTRACT

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**Introduction:** Central venous catheterization is usually performed during major surgeries for central venous pressure assessment and fluid therapy. Variety of techniques is employed in central venous catheterization but the information about pediatrics usage is limited. In this study we compared the electrocardiographic technique with landmark one for central venous catheterization. **Materials and Methods:** This is a cross-sectional study in 75 patients who underwent central venous catheterization for elective cardiovascular thoracic surgery. In the first step, the location of catheterization was estimated based on body surface landmarks. Then catheterization was done using electrocardiography. Then with cardio-surgeons aid, during open cardiac surgery, the catheter tip location was found (gold standard). Finally, chest X-ray was taken and catheter place based on radiological markers was recorded. **Results:** In this study 75 children with age under 18 years were included. The gender distribution was 42.7% females and 57.3% males. The mean depth of central venous catheter in gold standard method was  $7.5 \pm 1.35$  cm. Significant association between central venous catheter placement in gold standard technique and both landmark and electrocardiographic was seen ( $P$ -value  $< 0.001$ ;  $r = 0.94$  and  $P$ -value  $< 0.001$ ;  $r = 0.77$ ). Logistic regression showed a significant association between weight and placement of catheter tip in landmark technique ( $P$ -value = 0.038) as the following formula (Depth of central venous catheter =  $5.33 + 0.07 * \text{weight}$ ). **Conclusion:** Our study showed that the use of electrocardiographic for central venous catheterization considering carina-to-tip as reference was superior to the landmark. In addition, the correct position of catheter tip was affected by weight but not by height based on landmark technique.

## INTRODUCTION

Central venous catheterization (CVC) is usually performed during major surgeries for cardiac preload, central venous pressure assessment, and

for fluid therapy and injecting some intravenous medications centrally (1). Previous studies have insisted that the correct position of the catheter is the terminal one-third of the superior vena cava (SVC) near the venoatrial junction, but not enter

the right atrium (2, 3). This is important as failure in this procedure can cause life-threatening complications such as tamponade, pneumothorax, cardiac dysrhythmia, cardiac rupture and thrombosis (4).

The correct replacement of the catheter is important for reduction of the complications but actually 2-30% of catheter are reported to be placed abnormally (5). It is even more important in pediatric surgeries. Hence the correct position of the catheter tip should be checked usually using chest X-ray. Variety of techniques have been employed in CVC previously. The most common for pediatric patients were electrocardiographic (ECG) technique, landmark technique and catheterization through esophageal echocardiography (6, 7). Numbers of studies in pediatric patients are limited and also outcomes are controversial.

Hence we aimed to assess ECG technique with landmark one for central venous catheterization performance and compare their accuracy.

## MATERIALS AND METHODS

This is an analytic cross-sectional study conducted in 75 pediatric patients who underwent CVC because of elective cardiovascular thoracic surgery in Chamran Hospital (referral Cardiology hospital affiliated to Isfahan University of Medical Sciences) in 2016-2017.

Patients below 18 years of age who were the candidates for CVC and whose parents were willing for their child to participate in the study were included. Exclusion criteria were the inability to perform CVC through the right internal jugular vein, the presence of abnormal P-waves in ECG such as atrial fibrillation. In addition, patients with coagulopathy, extracardiac vascular abnormality, dextrocardia, and cardiac arrhythmia, the presence of in situ pacemaker and chest deformities were excluded as well. Patients' demographic information, including age, gender, weight, height and primary etiology of cardiac surgery were recorded in a checklist. All patients underwent right internal jugular vein catheterization, anterior approach(8), by a target fellowship of the cardiology anesthesiologist.

In the first step, the location of catheter was estimated based on body surface landmarks (from catheter entrance to second intercostal space). The next step was catheterization using ECG and the catheter fixed in its place with its location recorded. The P-wave shape was considered to determine the place of the catheter tip. Within the catheter, forward

movement from the superior vena cava to the right atrium increasing the P-wave height. The maximum P-wave height (lead II) was considered as right atrium entrance. Thereafter, catheter tip was pulled back until the reduction of P-wave height to one-third of maximum. This condition approximately equals with catheter presence in the terminal one-third of the superior vena cava, at the venoatrial junction (9). Then during open cardiac surgery, cardio-surgeon found the catheter tip location and its place was written in the checklist as the gold standard (connection of the superior vena cava with right atrium).

Finally, following surgical procedure cessation and during patients' stay at intensive care unit, portable chest X-ray was taken and catheter place was recorded based on radiological markers, including distance to the carina and anterior, posterior rib and vertebral parallelism of the catheter tip (10).

Gathered information was analyzed using SPSS version22 (IBM-United States). Descriptive were presented in mean and percentages. For analytics, T-test, Chi-square, One-way analysis of variance and linear regression were used. P-value<0.05 was considered as significant level.

## RESULTS

In this study included 75 patients below 18 years of age. The patient population included 42.7% females and 57.3% males. VSD and ASD were the most common cardiac anomalies with 34.7% and 26.7% prevalence, respectively. Demographic information including age, BMI, etc. of the studied population were collected (Table 1).

The of the CVC tip location through chest X-ray was assessed (Table 2). The distance of the venous CVC tip from carina was  $1.11 \pm 0.67$  centimeters. The prevalence of catheter position was posterior 6th rib (49.3%) and anterior 2nd rib (80%), and 5th thoracic vertebrae (49.3%). Also, the catheter position based on the surgeon's assessment is summarized in Table 4. The mean distance of catheter from carina was  $1.02 \pm 0.62$  cm. The the prevalence of catheter tip place was posterior 6thrib (51.6%), anterior 2nd rib (89.1%) and was 5th thoracic vertebrae (56.3%). Further information has been presented in Table 2.

The CVC depth in gold standard, landmark and ECG method were recorded (Table 3). The mean CVC depth in gold standard method was  $7.5 \pm 1.35$

centimeters. Paired T-test showed a significant difference between CVC embedding in landmark technique compared to ECG technique (P-value<0.001). In addition, there was a significant association between the difference in mean catheter depth embedded through both landmark and electrocardiography with gold standard technique (P-value<0.001).

Pearson correlation test shows a significant association between the CVC between gold standard technique and both landmark and electrocardiographic. This correlation was more in electrocardiographic technique (P-value<0.001; r=0.94 and P-value<0.001; r=0.77).

In the current study, catheter position was appropriate based on the surgeon's assessment in 85.3% of cases. Mean catheter position based on landmark was 6.49±1.02cm while according to electrocardiography, it was 7.34±1.24cm. These two techniques had direct significant correlation (P-value<0.001; r=0.83).

The other finding was about the association of gold standard and landmark techniques with weight, height, and body mass index (BMI). Pearson correlation test showed significant association with weight (P-value<0.001, r= 0.64 for gold standard and 0.60 for landmark) and height (P-value<0.001, r= 0.62 for gold standard and 0.57 for landmark) but not BMI (P-value>0.05). The linear regression assessment of the association of weight and height with CVC depth using the gold standard technique was performed. This analysis showed (Table-4) that the weight was an associated with landmark technique with the following model:

**The depth of central venous catheter = 5.33+0.07\*weight**

## DISCUSSION

CVC, a procedure usually utilized during major surgeries, like open thoracic cardiac surgeries have been almost always done through the internal jugular vein. This technique known as the anterior approach is approved by most of the anesthesiologists due to its easy percutaneous accessibility and straight predictable way to SVC. Moreover, studies have presented a success rate of over 90% using this catheter(11, 12).

Carina is the gold standard X-ray landmark for placement of the catheter tip used in previous studies (10, 13). This landmark has been raised as carina almost always at the place of pericardial reflection (14). This radiological landmark has been approved in pediatric studies (10).

In this study, we found that carina, the gold standard for CVC is directly associated with both electrocardiographic and landmark techniques. This was found while we have not taken chest X-ray prior to catheterization. This shows that both techniques are accurate enough for correct catheterization, as both were in direct correlation with X-ray findings. Furthermore, this correlation was more consistent with the ECG technique compared to the landmark. On the other hand, both techniques had a significant correlation with each other as well. It should be added that tip-to-carina distance was significantly less in ECG compared to landmark.

The novelty of our study is to assess tip-to-carina distance as the gold standard during cardiothoracic open surgery. The appropriate embedding had significantly less gold tip-to-carina distance compared to inappropriate embedding. Our findings were confirmed as we took chest X-ray after their admission at intensive care unit (ICU).

Findings of our study were consistent with the study conducted by Barnwal et al. where they found higher accuracy for ECG compared to landmark regarding carina as the gold standard marker for the tip of the catheter (4). The other study by Baldinelli et al. performed on elderly stated that up to 25% of patients underwent catheterization with landmark technique experienced failure. They concluded that use of ECG for CVC is safe, accurate and low-cost with minimum deviations of catheter tip distance to both carina and tracheobronchial angle (15). The other study by Koung-Shing et al. used transesophageal echocardiography as reference for the correct tip of the catheter. Our study confirmed that ECG is superior to landmark due to satisfactory outcomes achieved compared to landmark (16). But Lee JH et al. reported that ECG was not superior to the landmark technique (17). The aim of our study was to assess both techniques on pediatric patients. This minimizes differences found in other studies in two groups of patients. Thus, it can be better generalized to larger populations.

The other aim of the study was the association of weight and height with the appropriate location of the carina. Our findings suggested that the location of carina is not affected by height in the landmark, but it is significantly associated with weight. We have presented a model for measurement of ap-

appropriate catheter embedding presented in results.

Barnwal et al. in a similar study conducted in children who underwent cardiac thoracic surgery found a significant association between patients' age and the place of the venoatrial junction but not BMI (4). One limitation of our study was it does not find any association of age with the place of venoatrial junction. Also, the patients' age-range in our study was extremely wide. Another limitation of our study was not assessing complications following the catheterization.

## CONCLUSION

Based on our knowledge, this is the first study in which central venous catheterization using both landmark and electrocardiographic technique was assessed in a single population. Our study showed that use of ECG for CVC considering carina-to-tip as reference was superior to the landmark. In addition, the catheter tip correct position was affected by weight but not height in the landmark technique. Further studies in this regard are recommended.

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## AUTHOR CONTRIBUTIONS

All authors equally contributed in this study.

## CONFLICT OF INTERESTS

NONE

## ETHICAL STANDARDS

NONE

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**Table 1. Demographic information of the studied population**

Demographic variables	Results
Gender (n) (Male/Female)	43/32
Age in months (Medieval range)	12 (8-32)
Height in cm(Medieval range)	72 (66-87)
Weight in kg (Medieval range)	8 (6.5-10)
BMI in kg/m2 (Medieval range)	14.46 (13.31-15.83)
Atrioventricular septal defect (n)	7
Tetralogy of Fallout (n)	14
Atrial Septal Defect (n)	20
Ventricular Septal Defect (n)	26
Shunt (n)	4
Patent Ductus Arteriosus (n)	2
Tricuspid Stenosis (n)	1
Total anomalous pulmonary venous return (n)	3
Pulmonary Hypertension (n)	2
Tricuspid Atresia (n)	1
Pulmonary valve Stenosis (n)	1
Pulmonary valve Insufficiency (n)	2
Pulmonary valve Agenesis (n)	1

**Table 2. Assessment of CVC tip location based on chest X-ray**

Location of CVC tip	Number of patients (%)	Surgeon attitude		P-value
		Appropriate (N=64)	Inappropriate (N=11)	
Distance from carina (cm)	1.11±0.67	1.02±0.67	1.61±0.73	<b>0.006</b>
<b>Posterior rib border</b>				
5th rib	27 (36%)	26	1	<b>0.001</b>
6th rib	37 (49.3%)	33	4	
7th rib	9 (12%)	5	4	
8th rib	2 (2.7%)	0	7	
<b>Anterior rib border</b>				
2nd rib	60 (80%)	57	3	<b>&lt;0.001</b>
3rd rib	13 (2.7%)	7	6	
4th rib	2 (17.3%)	0	2	
<b>Vertebrae border</b>				
4th thoracic vertebra	2 (2.7%)	2	0	<b>0.002</b>
5th thoracic vertebra	37 (49.3%)	36	1	
6th thoracic vertebra	27 (36%)	21	6	
7th thoracic vertebra	7 (9.3%)	5	2	
8th thoracic vertebra	2 (2.7%)	0	2	

**Table 3. Comparison of landmark and electrocardiographic techniques accuracy for central venous catheter embedding**

Parameters	Mean (cm)	Standard deviation	Mean differences	P-value
Landmark	6.49	1.02	0.85	<0.001
Electrocardiography	7.34	1.24		
Difference of landmark and gold standard	1.007	0.86	0.84	<0.001
Difference of electrocardiography and gold standard	<b>0.16</b>	<b>0.42</b>		

**Table 4. Assessment of weight and height association with depth of CVC using the gold standard technique**

Techniques		Regression Coefficient	Standard error	T index	P-value
<b>Gold standard</b>	<b>Weight</b>	0.08	0.04	1.91	0.06
	<b>Height</b>	0.01	0.01	1.07	0.28
	<b>Constant</b>	5.46	0.79	6.89	<0.001
<b>Landmark</b>	<b>Weight</b>	0.071	0.033	2.13	0.036
	<b>Height</b>	0.006	0.01	0.50	0.61
	<b>constant</b>	5.33	0.62	8.48	<0.001