

Prediction of optimal right internal jugular vein catheter depth: comparison between Peres' formula and intracavitary ECG

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Abstract

Background: Incorrect central venous catheter (CVC) placement can lead to serious complications. In order to prevent complications, CVC insertion depth can be predicted using Peres' formula or intracavitary electrocardiography (ECG). The accurate prediction of optimal CVC depth using Peres' formula and intracavitary ECG on Malay race is unknown.

Objective: To compare the accuracy of Peres' formula and intracavitary ECG in predicting the optimal depth of right internal jugular venous catheter on adult Malay race.

Methods: This was a comparative analytic observational study with cross sectional design conducted at Cipto Mangunkusumo National General Hospital Jakarta from May to July 2017. After obtaining approval from the local ethical committee, right internal jugular venous catheter insertion was attempted on 111 patients, but 7 subjects were excluded from the study. Statistical analysis was performed on 104

samples to determine the accuracy of CVC depth prediction based on Peres' formula and intracavitary ECG using McNemar's test. The CVC depth prediction formula in adult Malay subject was calculated using linear regression based on its correlation with age, height, and body weight.

Results: The accuracy of intracavitary ECG and Peres' formula to predict the optimal depth of right internal jugular venous catheter was 75% and 11.5%, respectively. The difference between the accuracy of these two methods was statistically significant ($p=0.001$). Correlation analysis showed a significant relationship between height and the optimal depth of right internal jugular vein catheter. The CVC depth prediction formula obtained in this study was $4.143 + (0.058 \times \text{height in cm})$.

Conclusion: Prediction of right internal jugular venous catheter depth using intracavitary ECG is more accurate than the Peres' formula.

Key words: Adult Malay race, intracavitary ECG, optimal depth, Peres' formula, right internal jugular venous catheter.

Introduction

Incorrect central venous catheter (CVC) placement can cause serious complications that occur within one hour to a week after placement. (1) Placement of CVC that is too deep may cause cardiac arrhyth-

mias, interfere with the function of the right atrio-ventricular heart valve, and injure the heart and large blood vessels such as the superior vena cava. (1,2) Continuous friction between the tip of the CVC and myocardium can cause muscle erosion that triggers a cardiac tamponade which can be fatal in 50% of cases. (1) Placement of CVC that is too shallow can also cause problems as it will increase the risk of malfunction, malposition, migration to aberrant veins (i.e. azygos vein, internal mammary vein, brachiocephalic vein, subclavian vein, and jugular vein), and extravasation. (3)

To prevent complications from CVC deployment, CVC depth can be predicted in various ways, among others, using the Peres' formula or using an intracavitary electrocardiography (ECG) as guideline. According to the Peres' formula, the depth of CVC for the right internal jugular vein is height

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(cm) / 10. The advantage of using the Peres' formula is the practicality of the formula when used to determine the depth of CVC. (4,5) The use of intracavitary ECG for the CVC depth prediction is done by examining the P wave morphological changes. (6) Prediction of CVC depth with intracavitary ECG has a fairly high accuracy, safe, and able to replace the need for chest X-ray after CVC placement thus it can reduce radiation exposure to patients. (7)

The accuracy of optimum depth prediction of CVC using Peres' and intracavitary ECG formulas on Malay race is unknown. This study aimed to compare the accuracy of optimal depth prediction of CVC using Peres' and intracavitary ECG formulas on Malay race and optimal depth prediction formula of CVC based on its relation with age, body weight, and height of patient at Cipto Mangunkusumo National General Hospital.

Materials and methods

Research design

This was a comparative analytic observational study with cross sectional design. The study was conducted at Cipto Mangunkusumo National General Hospital Jakarta from May to July 2017. The minimum number of samples of this study was 104 subjects, which were calculated using sample formula for paired categorical analysis study. Research sampling was conducted after obtaining approval from the Ethics Committee of the Faculty of Medicine, Universitas Indonesia.

Research criteria

Patients above 18-year-old with body mass index (BMI) 18-30 kg/m² who had an indication of CVC placement and did not have a contraindication of CVC placement in the right internal jugular vein were included in this study after informed consent has been obtained. Exclusion criteria were patients with a history of arrhythmia, such as atrial fibrillation or supraventricular tachycardia, and patients with known anatomical heart abnormalities. Subjects will be dropped from the study if no P wave change was observed during CVC placement using an intracavitary ECG, there is difficulty in placing CVC with the right internal jugular vein, which cause the CVC to be placed in another vein, patient has life threatening complications, and when the chest X-ray showed the CVC tip did not end at superior vena cava.

Research procedure

Baseline data including patient's height was recorded and the CVC depth prediction was calculated

based on the Peres' formula which height (cm) divided by 10. CVC was placed using intracavitary ECG as a guide. Change in ECG was observed until the highest P wave was obtained (P-max). The maximum P wave height was recorded. If CVC was placed up to a depth of 20 cm and no morphological change in the P wave was obtained, the patient was dropped from the study. If an arrhythmia or P atrial wave occurred, the wire was immediately withdrawn. The CVC and the guidewire were pulled slowly until the P wave height is half of the P-maximum. It is at this depth that the CVC was fixed and its depth recorded. Chest X-ray was then performed in a supine position to evaluate whether the CVC depth was optimal using the criteria that the CVC tip was at ± 1 cm from the horizontal line as high as the carina. Any complications from the CVC placement within the first 24 hours were recorded and treated according to standard operating procedures.

Statistical analysis

Data that have been recorded was processed using SPSS program version 21.0. McNemar's test was used to find out which method between Peres' formula or intracavitary ECG was more accurate to predict the optimal CVC depth. Multivariate analysis was used to find correlations between age, body weight, and height with optimal CVC depth. Furthermore, the prediction formula of CVC depth was obtained using linear regression analysis.

Results

Study subject characteristics

One hundred and eleven subjects who met inclusion criteria and exclusion criteria were recruited for this study after signing informed consent. As presented in **Figure 1**, 7 subjects were dropped from the study due to CVC was placed in another vein (2 subjects) and no P wave change was observed (5 subjects), thus 104 subjects were analyzed in this study. The characteristics of study subjects including age, sex, body weight, and height were shown in **Table 1**.

Accuracy of CVC depth prediction based on Peres' formula and intracavitary ECG

Table 2 shows that the accuracy of CVC depth prediction based on Peres' formula (11.5%) is lower than intracavitary ECG (75%) when compared to chest x-ray. As shown in **Table 3**, there is a significant difference between the accuracy of the CVC depth prediction using Peres' formula and intracavitary ECG ($p=0.001$).

Correlation between age, body weight and height with CVC depth on adult Malay subject

In this study, only height has a significant correlation to CVC depth. Based on the Pearson test, there is a moderate correlation ($r=0.451$) between subject's height and CVC depth as shown in **Table 4**.

Prediction of CVC depth based on adult Malay subject height

The formula to predict CVC depth based on height which obtained through linear regression is presented in **Table 5**. The value of R^2 is 0.2 or 20% which means that the CVC depth variable can be explained by the patient's height only by 20%. All linear regression assumptions have been met.

Complication of CVC placement

Complication of CVC placement occurred in 8.6% patients (9 out of 104 subjects) in this study. Complications that occurred are described in **Table 6**. None of the complication was life-threatening and each complication was treated according to standard operating procedures.

Discussion

Study subject characteristics

This study was conducted on adult Malay race subjects aged 18 years and above. The average age of subjects who followed this study was 49.6 ± 15.6 years old. The age difference of adult subjects did not influence on CVC depth as a person growth is said to have stopped when reaching adulthood. The sex of the subjects in this study was fairly uniform, with 51% of male subjects and 49% of female subjects. Research conducted by Lum found that the accuracy of the CVC depth prediction using a formula based on height was not affected by gender. (3)

The average body weight of the subjects in this study was 58.9 ± 11.9 kg while the average height was 160.17 ± 7.6 cm. Average height of Indonesian population is shorter than Caucasian race, but almost the same as Mongoloid race, and taller than Indians. (8) Anthropometric studies comparing Malay, Mongoloid, and Indians show that average height Malays are higher than Mongoloid and Indian population. (9) Subjects in this study were limited by BMI between 18-30 kg/m^2 because in obese patients it can be found difficult to find anatomical markers for CVC placement in right internal jugular vein.

Peres' formula used in this study is a formula for predicting CVC depth by height. (5) In addition to the Peres' formula, there is also another formula that has been made to predict optimal CVC depth

based on patient height. (3,10) The average of CVC depth prediction with Peres' formula in this study was 15.7 ± 0.8 cm, whereas the average of CVC depth prediction with intracavitary ECG was 13.4 ± 0.9 cm. There was a difference of 2 (1-4) cm for the prediction of CVC depth between the two methods compared in this study. Study by Joshi, which also compared the prediction of CVC depth in the right internal jugular vein using the Peres' formula and ECG guidance, found that the difference in the CVC depth prediction between the two methods was 3.64 cm. (11)

Accuracy of CVC depth prediction based on Peres' formula and intracavitary ECG

In this study, the accuracy of CVC depth prediction in the right internal jugular vein based on Peres' formula was 11.5% after being compared with the chest X-ray. Several previous studies using Peres' formula for the prediction of CVC depth in the right internal jugular vein obtained varying accuracy values; study by Czepizak obtained 90% accuracy, study by Kim obtained 75% accuracy, and study by Joshi obtained 28% accuracy. (4,10,11) The accuracy of CVC depth prediction obtained in this study was different from previous studies due to differences in the subject population, average subject height, insertion point, and the criteria of CVC depth considered optimal.

Subjects in this study were Indonesian population with adult Malay race, similar with study by Perdana in the Indonesian population indicating that CVC placement in the subclavian vein using Peres' formula tended to be inappropriately positioned or deeper than desired. (12) Study by Czepizak conducted on Caucasian race; study by Kim conducted on Mongoloid race, study by Joshi conducted on the Indian population. The varied results can be due to anthropometric differences (especially height) between each race and population. This allows for a difference in the accuracy of the Peres' formula in determining the depth of CVC in the Indonesian population. (4,10,11,13)

CVC insertion point determined in this study was the point between the sternal head of sternocleidomastoid muscles and clavicle, as high as the cricoid cartilage. Study by Czepizak and other studies also used cricoid cartilage as a marker for the CVC insertion point in the internal jugular vein. (4,11,14) Peres himself did not mention the CVC insertion point used in his study that produced the Peres' formula. (5)

Anatomically, the most appropriate position for the tip of CVC lies from one third of the distal superior vena cava to the top of right atrium. The lower part

of the superior vena cava is coated by pericardial sac. Superior vena cava and pericardial sac cannot be identified on chest X-ray, while carina is a fairly easy identifiable radiological marker. (15,16) In this study, the optimal CVC depth was determined in the range of ± 1 cm from the horizontal line as high as carina on chest X-ray, in accordance with the study by Lee and study by Perdana. (12,14)

In this study, the accuracy of CVC depth prediction in the right internal jugular vein based on intracavitary ECG was 75% after being compared with the chest X-ray. Study by Lee found that the accuracy of CVC placement in the right internal jugular vein using intracavitary ECG was 95%, (14) while study by Sharma found that the accuracy of CVC placement in the subclavian vein using intracavitary ECG was 96%. (17) The difference of accuracy of CVC depth prediction using intracavitary ECG in this study can be due to different criteria of optimal depth of CVC. The optimal depth criteria of CVC used in this study was ± 1 cm from the horizontal line as high as carina on chest X-ray, whereas the optimal depth criteria of CVC in study by Sharma was from the carina to 4 cm above it. (17)

In this study, prediction of CVC depth in right internal jugular vein using intracavitary ECG result was significantly more accurate than Peres' formula ($p=0.001$), which was 75% and 11.5%, respectively. Study by Joshi found that the accuracy of the CVC depth prediction used intracavitary ECG was higher compared to Peres' formula, which was 92% and 28%, respectively. (11) The results obtained in this study are similar with study by Joshi in which the prediction of CVC depth using intracavitary ECG is more accurate than Peres' formula, although the percentage of accuracy is quite different. This may occur due to anthropometric differences from the study subjects in which study by Joshi was conducted in Indian population that are anthropometrically shorter than the Malay race. (8) The different criteria regarding the optimal depth of CVC placement can also influence as the optimal depth criteria of CVC in study by Joshi was from the carina to 4 cm above it, whereas the optimal depth criteria of CVC used in this study was ± 1 cm from the horizontal line as high as carina on chest X-ray. (11)

Prediction of CVC depth based on adult Malay subject height

Age, body weight, and height of the subjects in this study were analyzed to determine the correlation to the CVC depth prediction. The results found that the age and body weight variables did not have a

significant correlation with the CVC depth prediction. This is consistent with study by Kim, which also found that there was no significant correlation between CVC depth with age, weight, and BMI. (10)

Height has moderate correlation with CVC depth ($r=0.451$). This result differs from the study by Kim which found a minimal correlation between height and CVC depth ($r=0.22$; $p<0.05$). (10) The equation obtained from the results of linear regression analysis to predict the CVC depth by height was $4.143 + (0.058 \times \text{height in cm})$ with the value of R^2 obtained only 0.2 or 20%. The usage limitation of this formula is patients with height of 142 to 180 cm, in accordance to the minimum and maximum height of the subjects in this study.

Other studies have provided recommendations to predict CVC depth in the form of formulas. The depth of CVC in the right internal jugular vein based on the formula proposed by Lum is (height : 10) - 1 cm, while Joshi recommends the formula (height : 10) - 2 cm. All these formulas are modification of the Peres' formula, however it is not explained in detail whether the formula was obtained using a particular statistical analysis. (3,11)

Complication of CVC placement

Incidence of CVC complication in this study was 8.6% with the most complications being arrhythmias. This is different from study by Joshi, which found the incidence of complications was 38% with the most complications being arterial puncture. (11) Most arrhythmia that occur during CVC placement are temporary. The treatment performed is to withdraw the wire and CVC until the heart rhythm returns to normal and no further treatment is necessary. (18,19) Intra-atrial insertion is a form of malposition with incidence varies from 2 to 30% while in this study the incidence was 1.9%. (7) The treatment performed for this malposition is to reposition, in which the CVC is withdrawn until the tip is no longer in the atrium and reconfirmed by chest X-ray. (20,21) Arterial puncture with hematoma was complication with the least amount in this study (0.9%). Arterial puncture can occur in 4.2-9.3% of CVC placement and more common when CVC placement in the jugular region. Arterial blood vessel injury occurs in less than 1%. This can be minimized by the use of a small size needle for initial puncture and the use of ultrasound. (22)

Limitation of the study

This study has several limitations. First, there was an uneven time lag between CVC placement and obtaining chest X-ray in study subjects which al-

lows for migration of the CVC tip from the initial position. Although the risk has actually been minimized by fixating CVC on the skin, it still cannot fully ensure that there was no shift when chest X-ray was obtained. Another limitation is intracavitary ECG methods while more accurate than Peres' formula also have disadvantages. It is unusable in patients with cardiac arrhythmia, cardiac anatomic abnormalities, and when no P-wave changes are observed during CVC placement as occurred in 2 subjects in this study. One way that can be done to reduce this false negative is to retract the CVC and wire then deepen it again. (14) There is also absence of an absolute agreement on the optimal depth of the CVC deemed appropriate in the previous study. There are other variables (other than height) that also influence in predicting CVC depth that has not been accounted in this study as the ability of height variable to predict the optimal CVC depth is only 20%.

Conclusion

Prediction of right internal jugular venous catheter depth using intracavitary ECG is more accurate than the Peres' formula. The optimal depth prediction formula of CVC in the right internal jugular vein on adult Malay race was $4.143 + (0.058 \times \text{height in cm})$.

Conflict of interest

The authors report no conflicts of interest. The authors have no personal, financial, or institutional interest in any of the drugs, materials or devices used in the study.

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Table 1. Study subjects' characteristics

Characteristic	Values
Age (average±standard deviation, years)	49.6±15.6
Sex	
Male, n (%)	53 (51)
Female, n (%)	51 (49)
Height (average±standard deviation, cm)	160.17±7.6
Body weight (average±standard deviation, kg)	58.9±11.9
Average CVC depth prediction using Peres' formula (average±standard deviation, cm)	15.7±0.8
Average CVC depth prediction using ECG intracavitary (average±standard deviation, cm)	13.4±0.9
Average CVC depth prediction difference between 2 methods (cm), median (minimum-maximum)	2 (1-4)

Legend: CVC=central venous catheter; ECG=electrocardiography.

Table 2. Proportion of accurate CVC depth prediction based on Peres' formula and intracavitary ECG compared to chest X-ray

	Chest X-ray		Total
	Accurate	Inaccurate	
Peres' formula, n (%)	12 (11.5)	92 (88.5)	104 (100)
Intracavitary ECG, n (%)	78 (75)	26 (25)	104 (100)

Legend: CVC=central venous catheter; ECG=electrocardiography.

Table 3. Proportion of accurate CVC depth prediction based on Peres' formula and intracavitary ECG

		Peres' formula, n (%)			p*
		Accurate	Inaccurate	Total	
Intracavitary ECG, n (%)	Accurate	10 (9.6)	68 (65.4)	78 (75)	0.001
	Inaccurate	2 (1.9)	24 (23.1)	26 (25)	
	Total	12 (11.5)	92 (88.5)	104 (100)	

Legend: CVC=central venous catheter; ECG=electrocardiography; *=McNemar's test.

Table 4. Result of correlation analysis on age, body weight and height variables to CVC depth

Variable		p*
Age (years)	0.158	0.11
Body weight (kg)	0.224	0.22
Height (cm)	0.451	<0.001

Legend: CVC=central venous catheter; *=Pearson test, p is significant if <0,05.

Table 5. Linear regression equation to predict CVC depth by height (n=104)

Variable	Linear regression model	R ²
Height (cm)	$Y = 4.143 + (0.058 \times \text{height})$	0.20

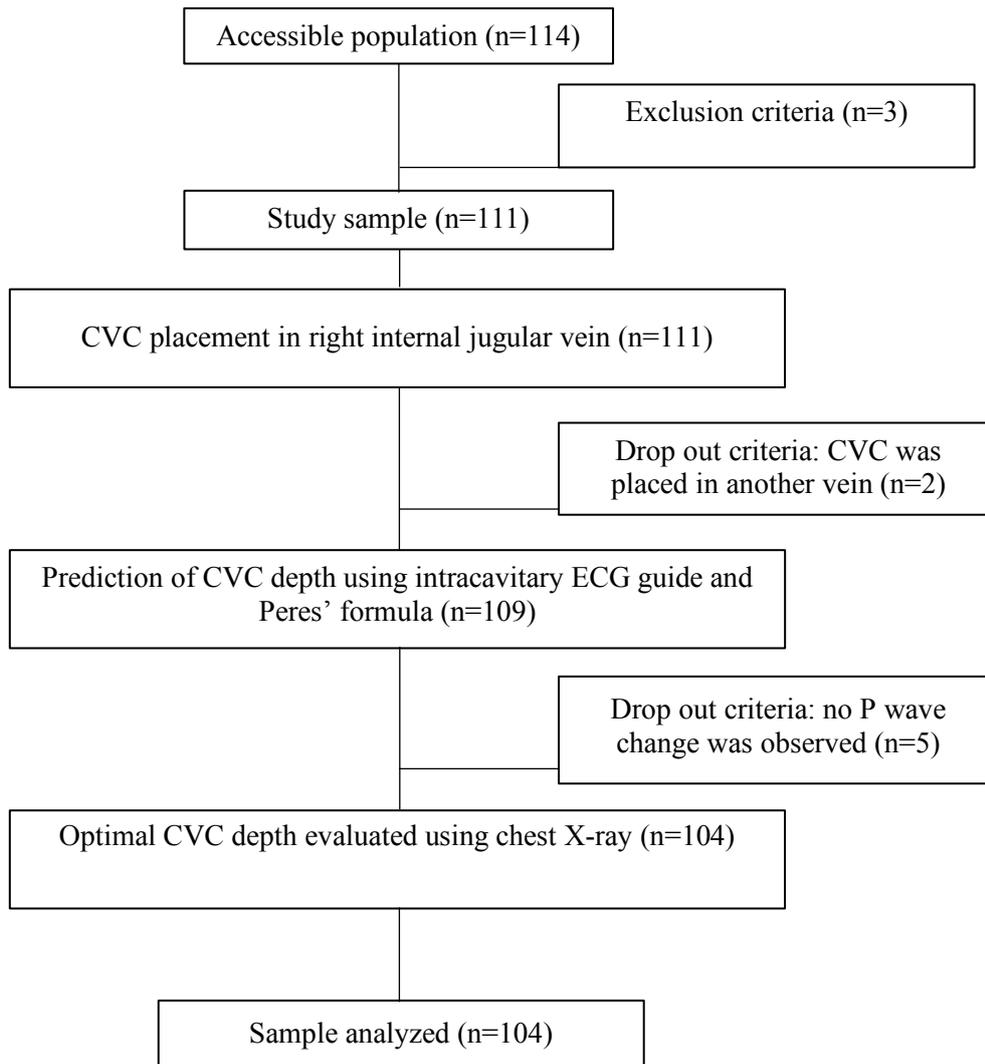
Legend: CVC=central venous catheter.

Table 6. Complication of CVC placement

Complication	Amount (%)
Arrhythmia	4 (3.7)
Intra-atrial insertion	2 (1.9)
Hematoma	1 (0.9)
Arterial puncture	1 (0.9)

Legend: CVC=central venous catheter.

Figure 1. Study subjects scheme



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