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The accuracy of peres' formula and topography anatomy in predicting the depth of CVC for installation in the right subclavia

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Abstract. Central venous catheter (CVC) insertion is a routine procedure in either intensive care or in perioperative circumstances. A simple and accurate method or rule is needed to predict the optimum depth of the CVC. The aim of this study is to evaluate the position and depth of CVCs using Peres' formula ([height/10]-2) and landmark measurements, as well as assessing the incidence of malpositions of CVC installation. This research was an analytic observational study. Fifty patients undergoing central venous catheter (CVC) installation with the right subclavian vein approach were divided into two groups: a Peres' formula ([height/10]-2) and an anatomy topography measurement group. The results of the calculations were used to determine the boundary prediction of skin fixation. CVC depth was evaluated by measuring the distance between the distal end of the CVC and the carina, from chest radiographs. The measurement results were analyzed by a Bland and Altman plot. The patient's characteristics were equal for both groups. In the Peres' formula group we found that the mean of the distal CVC was 1.5 (0.82) cm under the carina (CI 95%: 1.2 to 1.9 cm), with the limit of agreement as 0.0 cm to 3.0 cm. The mean of the landmark group was 0.85 (0.73) cm (CI 95%: 0.5 to 1.1 cm) with the limit of agreement as -0.5 cm to 2.2 cm. The incidence of malposition was found to be similar in both groups. The results showed that both prediction methods are not accurate enough to predict the depth of CVC insertion in Indonesian people.

1. Introduction

CVC insertion is a routine action in intensive care units (ICU) and perioperative environments. Many conditions and needs require the installation of CVCs including the measurement of central venous pressure (CVP), chemotherapy, and providing parenteral nutrition. During the period January to June, 2015, in the Cipto Mangunkusumo Hospital (RSCM), 41 CVC insertions occurred in the ICU, 183 insertions of CVC occurred in the operating room, and 153 insertions of CVC occurred in the emergency room. Installation of a CVCs is not without the risk of complication. These complications are directly related to vein puncture such as hematoma, infection, pneumothorax, and puncture of arteries, and there are various negative impacts related to the malposition of the end of the CVC [1-3]. The Food and Drug Administration guidelines cite many complications and document a strong consensus that the ends of the CVC cannot be located in the heart [4-6]. This can cause arrhythmia, a perforated heart, thrombosis impact embolus, and cardiac tamponade which has fatal effects [1-7]. Shamir *et al*. examined 16 cases of arrhythmia from 49 cases of CVC installation [8]. The placement of the tip of the CVC in this position can still cause cardiogenic of tamponade [9, 10]. Installation of CVCs with an inaccurate depth can position the end of the catheter in the brachiocephalic vein although there are other veins which culminate in the superior vein cava (SVC). The end of the catheter in this position can triggered the irritation of blood vessels and form a thrombus that can cause pulmonary embolisms [11]. Solorzano *et al*. performed retrospective studies of 73 patients who had CVCs installed and found there were 43 (58.9%) malpositioned, 30 (69.7%) placed too deep, 7 (16.2%) placed too shallow, and 6 (13.9%) is not on accurate SVC [14]. In adult patients, the accurate catheter depth of a CVC can be estimated using Peres' formula or various methods of topography anatomy [13-17].

In 1990, Perez published the formula of depth prediction for CVC for various places of insertion [13]. Perez used anteroposterior chest radiography after the installation to observe the position of the catheter tip. At that time, the depth of the catheter was considered ideal when located in the superior cava vein. Perez calculated the formula for pairing CVCs with various approaches such as right subclavian ([height/10]-2); left subclavian ([height/10]+4); and right internal jugular vein (height/10). Perez defined malpositions as either malposition intra-thorax (intra-atrium/brachiocephalic vein/inferior vena cava) or malposition extra thorax (jugular veins intern/other veins) [13]. Peres's formula is reported to have low accuracy when the carina is used as the point of reference for CVC depth accuracy [18]. In a study from India of 50 CVC placements that used Peres' formula, 76% of catheters ended under the carina, 16% were malpositioned in internal right jugular veins or left of subclavian veins [18]. Some years ago, a prediction method was developed for the correct depth placement of CVCs by measuring the distance between the points of reference using anatomical topography. Choi *et al*. tested three methods of prediction, namely: measure the distance from the highest point of insertion of the subclavian vein and add the vertical distance to the carina (I-T-IC); measure the shortest distance between the insertion point to the right clavicular and add the distance to the clavicular fossa to the second point (I-C-IC); and measure the distance from the insertion point to the clavicular fossa (I-IC). The last two methods were shown to have lower prediction values than the first method [17]. The first method is more effective than the other two methods examined, but it does have flaws that must be overcome by using ultrasonography (USG) to determine the peak of the subclavian vein.

Other research undertaken by Ryu *et al*., carried out on 153 CVCs via the right subclavian, measured the depth prediction between the insertion point and the clavicular. The results were 95% CI: 0.2 cm above the carina, -0.2 cm under the carina [16]. In this research, the insertion distance to the clavicularis fossa was measured directly from the patient and the carina distance to the clavicularis fossa was measured from chest radiography. The subclavian approach has a risk of pneumothorax complications greater than the approach of the internal jugular, but the subclavian approach is still used because it provides more patient comfort especially in patients who use CVC long-term (i.e., chemotherapy) or for patients who have contraindications in the pairing jugular area. The estimation of the depth of accurate CVC placement requires a method or a simple formula. This research aims to test and compare the accuracy of Peres' formula to a method of anatomical topography using the parallels between the tip of the catheter and the carina in breast radiography as the parameter of prediction method accuracy.

2. Materials and Methods

This research was an analytical cohort study of 50 subjects that had undergone CVC placement with the approach of the right subclavian. This research aimed to evaluate the position and depth of a CVC using two methods of predicting the depth of the CVC. Namely Peres' formula ([height/10]-2) and the measurement of anatomy topography. The sampling method was randomized toward two groups. The criteria of inclusion were: that the subject agreed and signed an approval form after receiving an explanation; was aged 18–75 years; had a body mass index (BMI) between 18–30 kg/m^2; had a chest radiography before the action; there was no indication of the installation of the CVC; and no contraindications of CVC pairing of the right subclavia. The criteria of exclusion was; patients with repeated stabbing more than three times, or the first stabbing directly of the subclavia artery; there were abnormalities in the area of anatomy stabbing; there were severe coagulant status disorders (i.e., thrombocytes <50,000/mm^3, fibrinogens <1.20 g/l, PTT > 50 seconds, INR < 0.5). The expulsion criteria was, that if from the results of the chest radiograph, the end of the CVC was not in the SVC (calculated as a malposition case), or patients received threatening complications. The study methods were adopted from the Standard Operating Procedures (SOP) of the RSCM. In the group that used Peres' formula, the prediction calculation ([height/10]-2) was done before installation. For the group that used topography anatomy, calculation of the distance between the sternal glands alignment notch and the carina from the breast radiography was done using a sterile paper ruler. The chest radiography was done after the action for the evaluation of the depth of the CVC. The collected data was analyzed with SPSS V21.0. The statistical analysis used the Bland-Altman plot.

3. Results and Discussion

3.1 Results

In this research, informed consent was received from the 50 patients who had an installation of a CVC into the subclavia with the approach of the right subclavia in RSCM. Six patients were rejected from the research because the tip of the CVC was not in the SVC according to the results of the chest radiographs post CVC installation. These cases calculated as malposition case in the data. The data characteristics of the research subjects included gender, age, height, and body weight. Males and females were equally represented in this research. The average age of the subjects was 42.40 years in the Peres' formula group and 49.52 years in the topography anatomy group. The average height was 158.56 cm in the Peres' formula group and 160.56 cm in the topography anatomy group. The average body weight was 59.1 kg in the Peres' formula group and 61.5 kg in the topography anatomy group. Table 1 shows the characteristics of the research subjects.

Table 1. Characteristics of the research subject

	Peres (n=22)	Anatomy topography (n=22)
Gender		
Male	9 (40)	9 (40)
Female	13 (60)	13 (60)
Age (years)	42.40 ± 15.31	49.52 ± 14.62
Height (cm)	158.56 ± 7.57	160.56 ± 7.04
Body weight (kg)	59.1 ± 11.9	61.5 ± 12.6

Bland and Altman plots were used to find the match between the two measurements in this research; Peres's formula and topography anatomy. The determination of compliance can be seen from the limit of agreement. On the graph of the Bland and Altman plot above (Figure 1), the value of the average of the difference for both measurements is 1.18 cm, with an CI of 95%, is 1.01 cm to 1.36 cm. The value of the limit of agreement was -0.03 until 2.36. This figure was obtained from the average ± 1.96 x SD. From the results it could be seen that most of the sample is located in the limit of agreement region. These results could not prove the existence of the match between the two prediction measurements of carina.

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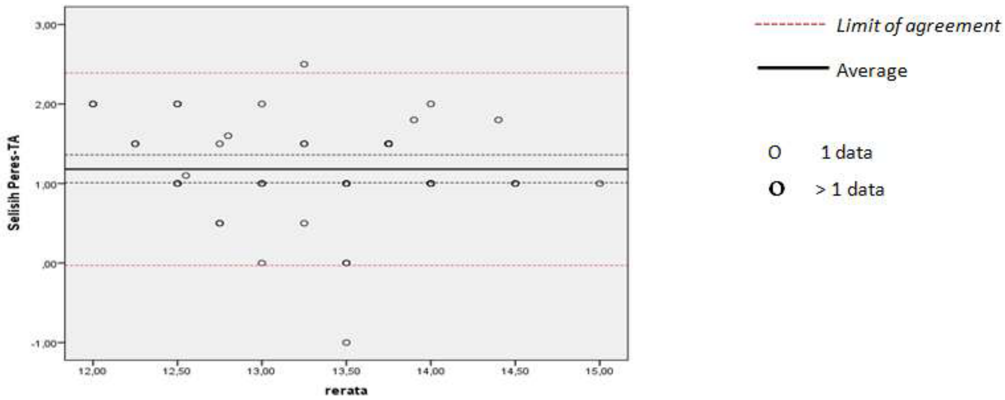

Figure 1. Graph of Bland and Altman plot difference prediction equations of Peres' formula against topography anatomy

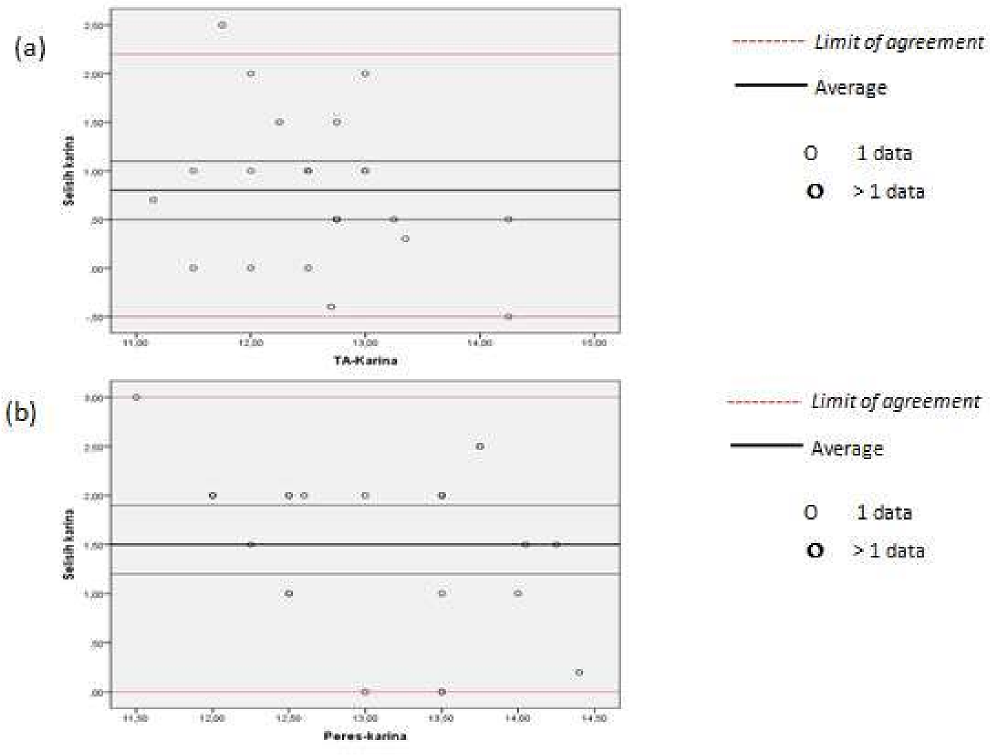

Figure 2. Graphs of Bland and Altman plots. (a) Difference of prediction of topography anatomy of carina. (b) Difference of prediction of Peres' formula against carina

On both the graphs above (Figure 2) the results of both the measurements have more tendency in the carina. However, the measurement of the topography anatomy had a distance difference closer to the carina compared the measurement from Peres's formula.

3.2 Discussion
Installation of the CVC in this research was done on the right subclavia vein using the appliances of the CVC, i.e., Bbraun® and Arrow®. Comparison between both of the appliances has been done

previously and it was found that both the appliances have the same length. Comparison of the accuracy of the results of the second prediction measurements were analyzed using the Bland and Altman plot. The Bland and Altman plot is a statistical method developed by Martin Bland and Douglas G. Altman. The test statistics are used to compare the measurement results of two or more methods. The results of these statistical tests can be agreement (compliance) or validity (the diagnostics). In this research, both the measurement methods were employed for the analysis. This test, of the suitability of both the measurements, was not based on the value of p, but based on the limit of agreement.

The subject of the research was adult patients aged 18–75 years who had a CVC installation in a central vein with the approach of the vein being the right subclavia. The determination of adulthood is more than 18 years of age. From the characteristics of the basic data obtained, the difference means between the groups, Pere's formula and topography anatomy, was determined by an independent sample t-test ($p > 0.05$). Both groups were considered equal so they could be compared. The randomized sample numbers for each group were equal. Ryu *et al*., obtained an average subject age of 51.6 years; average subject height of 159.4 cm, and average subject weight of 61.8 kg. Sharma D's research in India obtained an average age of 53.5 years and an average height of 159.32 cm. These anthropometric measurements were quite similar to those of the current study. The end of the distal of the CVC in the central vein is expected to be as high as the carina. Installation of the CVC too deeply can cause arrhythmia, a perforated heart, thrombosis impact, and tamponade of cardiogenic which have fatal effects. The safe depth is considered to be not more than 1 cm under the carina [16]. Pairing of CVC too shallow is considered to increase the risk of excluding cardiogenic and perforated veins. The determination of the carina as the safety point of installation of CVCs is based on several studies including Albrecht *et al*. who found that the carina is always located above the pericardium with an average distance of 0.8 cm [19].

In the group of Peres' formula, the distal tip of the CVC that were more than 1 cm under the carina was obtained for 15 samples (68%). The Bland and Altman plot determined the average difference in the distal tip of the CVC is 1.5 (0.82 cm) under the carina, with the limit of agreement being 0.0 cm–3.0 cm. Peres's formula could not be applied in Indonesia because the position of the distal tip of the CVC is greater than desired. In addition, Peres' formula method of prediction had a limit of agreement that was too large for the average margin, meaning that the Peres' formula method is too diverse for different subjects. Sharma *et al*. [18], got similar results, where 76% of the ends of the distal catheter obtained were under the carina. The variance of difference for the distal tip of the CVC against the carina, probably caused by the differences in the anatomy of the population, was examined by Peres using the population of the initial research. Peres's formula predicts that height affects the depth of the CVC. The depth of the CVC is comparable with an extension height. The height of Indonesians is generally shorter than the height of Caucasian races so that the depth obtained is shorter than Peres' formula. In the topography anatomy group 40.9% of the data was located in the limit of agreement expected by the researchers (±1 cm from the carina). A review of the Bland and Altman plot obtained an average 0.85 (0.73 cm) with the value of the limit of agreement as -0.5 cm to 2.2 cm. It was concluded that the limit of agreement in this research was too large and was located further from the limit of agreement than was expected by the researchers. This result is quite different from the research done by Ryu [16] where a of result 0.0 ± 1.2 cm (95% CI: 0.2 until -0.2) was obtained. Ryu's research used six samples the position above the carina.

In this research there were differences compared to the results obtained by Ryu, probably caused by the difference in anatomy between the two populations. Although the characteristics of the data from the two studies are almost the same there still could be differences in anatomy. This can be seen from the difference in the calculation of the distance of the clavicular alignment notch to the carina. In this research the average was 5.3 ± 0.4 cm while in the research by Ryu *et al*, the average was 7.0 ± 1.3 cm. The researchers assumed that there are differences in the anatomy between the two research populations. In this research it could be seen that both methods do not have good accuracy for predicting the depth of the CVC right subclavia with the carina as a reference. Both methods have a tendency to go under the carina, however, the method of topography anatomy had a smaller difference against the carina compared to Peres's formula for prediction. This research found six subjects that experienced malposition, two samples were malpositioned to the left of the vein subclavia, three samples were malpositioned to the right of the jugular vein, and one sample was located on the other vein. Research by Sharma *et al*. [18], also found 16% malposition cases with the CVC positioned in the jugular vein of right internal and left subclavia vein.

The malposition CVCs may be caused by the change of the "J" tip guidewire or too deep an insertion from the guidewire. According to research by Zuniga *et al*. [6], the end of "J" guidewire should be pointing to the caudal with a maximum depth of 16 cm. Another possibility, that can cause a malposition, is the position of the head and shoulders when pairing. The position of the head if facing opposite to the installation location will increase the angle between the SVC and internal jugular vein (IJV) that enables a malposition toward the IJV. This research did not find any signs of complications, such as arrhythmia, in the subjects with an installation of a CVC that exceed the carina, so the numbers predicted to exceed the carina were not considered clinically significant. In were weaknesses in this research. During the research we found a difference in the appliance imaging radiology, where there is a difference between the tools used in the emergency room and the HCU room. The tools used in the HCU do not have a facility to display the zoom scale or the diminution of the chest radiography. This could be minimized by using a metal ruler for orientation. Additionally, different angles of the chest radiography were used that can cause changes in the distances of the chest radiography results. In this research, the radiography angle of the chest was not the same for the radiographs taken before and after the installation of the CVCs. Additionally, another weakness was the differing knowledge of the operators installing the CVC about the prediction methods that could allow for bias in the installation. This could be minimized by researchers educating the operators installing the CVCs orally and by providing leaflets that contain the proper installation techniques and the calculation of both the prediction methods.

4. Conclusion

The predicted depth of a CVC right subclavia installation using Peres' formula and topography anatomy, with the carina as a reference, do not have the same accuracy. The depth of a CVC right subclavia prediction using anatomical topography is no more accurate than the prediction of the depth of the CVC right subclavia using Peres' formula. The number of malpositioned CVC cases is the same for both prediction methods.

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