Assessment of the Tip Position of Central Venous Catheters Inserted Using Peres’ Height Formula

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Abstract
Objectives: The tip of a central venous catheter (CVC) should be positioned in the proximity of the cavo-atrial junction (CAJ) where the lower third of the superior vena cava (SVC) and the upper right atrium (RA) are located to prevent life-threatening complications. This study aimed to determine the accuracy of Peres’ height formula in predicting the correct insertion depth of CVC.

Methods: A total of 332 patients were enrolled in this prospective observational study. All CVCs were inserted using Peres’ formula. The ‘correct’ tip position of CVC was the placement of the CVC tip 1 cm above and 1 cm below the carina in CXR. Rates of correct placements for each side and site of catheter insertions, gender, and body mass index (BMI) differences were evaluated.

Results: The correct placement rate of all catheters was 74.4%. There were statistically significant correlations between the correct placement of right-sided jugular and subclavian catheters (p<0.001) and left-sided jugular and subclavian catheters (p=0.014). There was a statistically significant difference in male patients (p=0.047). Higher BMI resulted in a lower rate of correct placement with no statistically significant difference (p=0.457).

Conclusions: Peres’ formula can be easily used to determine the correct position of CVC tips with a success rate in the Turkish population. However, practitioners should be aware of the low accuracy rate of Peres’ formula in female patients (68.5%) and patients with BMI over 35 kg/m² (62.5%).

Introduction
Central venous catheters (CVCs) are inserted in many critically ill patients for parenteral nutrition and antibiotic therapy as well as patients who require chemotherapy, hemodialysis, patients with difficult peripheral venous access, and surgically ill patients for blood transfusion [1].

It is important to place the catheter tip in the correct position to prevent life-threatening complications such as arrhythmias, and erosion of the right atrium (RA) or right ventricle leading to hemothorax, hydrothorax, or cardiac tamponade. Perforation of the superior vena cava (SVC) can be seen especially during the insertion of left-sided CVCs [2]. The optimal position of the tip also provides the correct measurement of central venous pressure. The tip of a CVC should be positioned in the proximity of the cavo-atrial junction (CAJ) where the lower third of the SVC and the upper RA is located [3]. This position is above the level of pericardial reflection [4]. This is a safe area where the complication rate decreases. A ‘high’ tip position site is on the upper or middle third of the SVC and is related to pain during injection of drugs, thrombosis, and infection. A ‘low’ tip position site is on the inferior vena cava or through the tricuspid valve or the right ventricle. It is also recommended that the catheter tip should not touch the vein wall [5].

There are no gold standards for estimating the insertion depth of a CVC. It is essential to check the correct position of the catheter tip before use. The assessment of the tip of CVC can be performed during and after the insertion. Surface landmarks, simple formulas, fluoroscopy, right atrial electrocardiography (ECG) and ultrasonography (USG), as well as transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE), can be used during the procedure [6-10].

The present study aimed to determine the accuracy of Peres’ height formula in predicting the correct insertion depth of CVC.

Materials And Methods
After obtaining approval from İzmir, Bozyaka Education and Research Hospital Ethical Committee (approval number: 04.07.2018-6), 332 patients within a one-year period, aged between 18 and 70, were enrolled in this study.
prospective observational study. The patients provided written informed consent. Patients with a history of previous neck surgery, abnormal anatomy of the neck, local infection of the neck, chest deformities (e.g., pectus carinatum, pectus excavatum), pacemakers, and coagulopathy were excluded.

Age, gender, weight (kg), height (cm), and body mass index (BMI) (kg/m²) were recorded as demographic data. Patients were divided into four groups according to the BMI: BMI Group 1: 18.5–24.9 kg/m², BMI Group 2: 25–29.9 kg/m², BMI Group 3: 30.0–34.9 kg/m², and BMI Group 4: ≥35 kg/m². All CVCs were placed with aseptic precautions, using the Seldinger method by an intensivist in the intensive care unit (ICU) or an anesthesiologist in the operating room (OR). Peres’ formula was used for the depth of insertion. According to this formula, the lengths for CVC insertion should be height/10 cm for the right internal jugular vein (IJV), (height/10) - 2 cm for the right subclavian vein (SCV), (height/10) + 4 cm for left IJV and (height/10) + 2 cm for left SCV. Triple-lumen catheters (Arrowg+ard Blue® Three-Lumen CVC, Teleflex Medical, Westmeath, Ireland) were used. The patient’s head was turned to the opposite side from the site of insertion. The insertion point was at the level of the cricoid cartilage, and the level of the apex of the two heads of the sternocleidomastoid muscle when IJV catheterization was performed. The SCV catheterization was performed through an infraclavicular approach at the midpoint of the clavicle. Side (right/left) and site (IJV/SCV) of insertion, number of insertion attempts, and complications such as arterial puncture, hematoma, arrhythmias, pneumothorax, and subcutaneous emphysema were recorded.

Postprocedural anteroposterior (AP) CXR was taken in a supine position with the patient’s arms beside of the chest to assess the CVC tip position and complications. The CXR images were assessed from the Picture Archiving & Communication System (PACS) with the measurement of the vertical distance between the CVC tip and the carina by a radiologist.

The definition for the ‘correct’ tip position of CVC was the placement of the CVC tip 1 cm above and 1 cm below the carina. If needed, the catheter was repositioned by pulling back or changing the catheter through a guide wire for a further distance. The CXR was also used for the correct placement of the CVC tip after repositioning. The primary endpoint was defined as the need for catheter repositioning.

Statistical analyses were performed with the Statistical Product and Service Solutions (SPSS), version 21.0 (IBM Corp., Armonk, NY, USA). Demographic data had a non-normal distribution, so presented as the median (interquartile range (IQR)). Catheter insertion sides, complications, correct placement of CVC tips, and repositioning of catheters were presented as numbers (n) and percentile (%). Correlations between the correct tip position and insertion side, gender, and BMI were determined using the chi-squared test. A p-value lower than 0.05 was considered statistically significant.

Results
A total of 332 patients were enrolled in the study. There were 202 (60.8 %) male and 130 (39.2%) female patients. Demographic data are listed in Table 1.

|       | Min to Max | Median | IQR |
|-------|------------|--------|-----|
| Age   | 18-70      | 65.5   | 20  |
| Height (cm) | 150-198 | 168    | 14  |
| Weight (kg)  | 45-150 | 73     | 13.75 |
| BMI    | 18.3-66.7  | 25.59  | 4   |

TABLE 1: Demographic data
Min: Minimum, Max: Maximum, BMI: Body mass index, IQR: Interquartile range

The number of CVCs inserted through the right IJV was 157 (47.3%), and 163 (49.1%) catheters were inserted through the right SCV. The number of catheters placed in the left IJV and left SCV was the same i.e., six (1.8%). A total of 247 (74.4%) CVC tips were in the correct position. The number and percentile of correct placement of CVCs according to the side and site are shown in Table 2.
|                | Number of catheterizations (n) | Percentage of catheterization (%) | Number of correct tip positions (n) | Percentage of correct tip position (%) |
|----------------|--------------------------------|-----------------------------------|-------------------------------------|----------------------------------------|
| Right IJV      | 157                            | 47.3                              | 133                                 | 84.7                                   |
| Right SCV      | 163                            | 49.1                              | 106                                 | 65                                     |
| Left IJV       | 6                              | 1.8                               | 6                                   | 100                                    |
| Left SCV       | 6                              | 1.8                               | 2                                   | 33.3                                   |
| Total          | 332                            | 100                               | 247                                 | 74.4                                   |

**TABLE 2: Summary of catheterizations and correct tip positions**

IJV: Internal jugular vein, SCV: Subclavian vein

Correct placements for the right IJV and SCV are shown in Figure 1 and Figure 2.

**FIGURE 1: Correct placement of right internal jugular vein catheter**

Red arrow: Tip of the catheter, Blue arrow: The carina
There were statistically significant differences between the correct placement of right IJV and SCV catheters (p < 0.001) and left IJV and SCV catheters (p=0.014). The number of left IJV and SCV catheters was low. So, the difference between the correct placement of the left IJV and left SCV catheters was thought to be insignificant although the p < 0.001. A total number of 85 (25.6%) catheters were repositioned, where 70 (21.1%) catheters were pulled back and 15 (4.5%) catheters were reinserted for further distance. The incorrect placement of a left IJV catheter, which was located more than 1 cm below the carina, is shown in Figure 3. Postprocedural CXR images of all repositioned CVCs demonstrated correct placement.
The rate of incorrect placement of CVC tips was 31.5% (n=41) in female and 21.8% (n=44) in male patients. There is a statistically significant difference between the correct placement of CVC in male patients compared in female patients (p=0.047). It was seen that 33 (75%) of 44 catheters in male patients and 37 (90.2%) of 41 catheters in female patients were pulled back. The rates of reinsertion to a further distance of CVCs in male and female patients were 25% and 9.8% of all repositioned catheters, respectively.

There were 16 patients with BMI over 35 kg/m$^2$. The CVC tips of six (37.5%) of these 16 patients were in the incorrect position. There is not a statistically significant correlation between the correct placement of CVCs and BMI (p=0.457).

Arterial puncture occurred during the placement of 4 (1.2%) catheters, whereas arrhythmias were detected during insertion in 35 (10.5%) patients. Pneumothorax, subcutaneous emphysema, and hematoma were not seen.

**Discussion**

The results of the study, where Peres' formula was used for the insertion depth, showed that 74.4% of all CVC tips were placed in the correct position in the Turkish population. The success rates are 84.7% for the right IJV and 65% for the right SCV. These results are lower than the results in Peres' study. This difference was thought to be due to the anatomical variations among populations.

Peres first described the formula based on the patient's height in 1990 [7]. Recommendations for the length of catheter insertion vary with the site and side of insertion. It is recommended that the right SCV catheters should be inserted to a height of 10 cm to 2 cm. The recommended length of the right IJV catheter is a height of 10 cm. Peres has noted that no recommendation can be made for left IJV and left SCV catheters because of the small numbers. The formula also does not take into account the insertion point, anterior, posterior, or central approach for IJV catheterization and as well for supra/infraclavicular SCV catheterization.

Kim et al. recommended a calculation about depths of CVC insertion: 14 cm for the right SCV, 15 cm for the right IJV, 17 cm for the left SCV, and 18 cm for the left IJV, based on the distance from the CVC insertion point to the RA/SVC junction for Asian populations [11]. They used computed tomography (CT) and compared their recommended calculation with Peres' formula. Peres' formula predicted the optimal position of CVCs with an accuracy of 75% for the right IJV and 62% for the left IJV. They found that the calculations are more accurate (89% to 95%), more simple to use, and need less repositioning. In the present study, a
similar accuracy was demonstrated: 84.7% for the right IJV and 65% for the right SCV. This accuracy is thought to be due to the similarity of the Asian population’s mean height with that of Turkish subjects. Kujur et al. suggested an insertion depth of 16 cm may be adequate for the western population regardless of site and side of insertion, but the Indian population may require a shorter length of placement [12]. Russel et al. suggested a shorter length of 15 cm for the CVCs to be appropriate [13].

Complications such as arrhythmia, sepsis, vessel perforations, cardiac tamponade, embolism, thrombosis, hydropneumomediastinum, and pneumothorax have been reported due to incorrect placement of CVCs [14,15]. In the present study, none of the patients demonstrated pneumothorax or other life-threatening complications. The CVCs were not evaluated for thrombotic and infectious complications in long-term follow-up. Peres also noted low complication rates, with only malposition and arterial puncture [7].

There have been many studies for optimal positioning of CVC tips to prevent complications. The most effective method has been reported to place the CVC tip in SVC, out of the heart, and to check the correct placement with chest radiography [4]. The SVC-RA junction is considered the optimal zone. When the catheter tip is in the upper middle SVC, thrombosis and migration of the catheter tip into an azygous or innominate vein can be seen. When the catheter tip is in the RA, arrhythmias and cardiac tamponade are the main problems [5].

Kang et al. investigated the tip-to-carina (TC) distance on chest CT and CXR images as many studies have studied [18]. They have demonstrated CT distance as a simple and precise method to confirm not only the correct placement of the CVC tip but also its optimal position for accurate hemodynamic monitoring.

Opposite to all other studies, Struck et al. reported that all calculated formulas had a low likelihood of atrial positions but high risks of proximal mal-positioning [20]. Thus, they did not recommend formulas, considering inter-individual differences in vascular anatomy.

The CXR is usually preferred to determine the correct position of the CVC tip. Radiation exposure is the main concern about CXR imaging. It is generally used post-procedural, so extra time is needed. It can be available during the procedure only with portable X-ray devices or in catheterization laboratories. Topographic methods are thought to be more reliable to determine the correct positioning as there is no need for extra equipment and cost.

The USG is a cost-effective, intraprocedural, and real-time imagining. Chui et al. reported that a routine postprocedural CXR is unnecessary after ultrasound-guided CVC insertion as pneumothorax and catheter misplacement were rare [23]. Ultrasound guidance is associated with an increased first-attempt success rate, a reduced number of puncture attempts, and fewer complications when compared with the landmark technique [24]. Micro-convex probe is one of the probes that have been used. However, it is feasible only during internal jugular cannulation in adult patients [25]. Disadvantages of the USG technique, including TEE, are the requirement of special equipment and a trained practitioner.

The AP CXR was preferred to confirm the correct position of the CVC tips in this study. The CXRs were examined after the insertion of CVCs by a radiologist. All measurements were made using PACS.
There are some limitations in this study. Firstly, CVCs were inserted by different specialists. Although insertion points were determined by the surface landmarks, these points may have varied according to the practitioner and patient’s head position during insertion. Secondly, CXR images were evaluated after the procedure. There have been other studies where CT imagining was used [11]. The tip of the CVC may have migrated during the transport period. The patient’s position was not checked during imagining as well. Over-extension of the head causes a cephalad position of the tip of CVC. Although the results were statistically analyzed for gender and BMI, age was not taken into account. On the other hand, rates of correct insertion of left-sided catheters did not reflect the real rates due to the small number of patients. Further studies should be planned in a large number of patients with a BMI over 35 kg/m².

Conclusions
Each catheter tip should be confirmed with an imagining method for correct placement. Development in the field of radiology has led to high-quality imagining methods. However, providing the required equipment and trained practitioners are the main difficulties. So, CXR is still useful for the determination of the CVC tip position. Peres’ formula can be easily used for the correct position of CVC tips with a success rate of 74.4% in the Turkish population. Practitioners should be aware of the low accuracy rate of Peres’ formula in female patients (68.5%) and patients with BMI over 35 kg/m² (62.5%). Further studies with other measurements and different patient groups are needed to achieve higher success rates.

Additional Information
Disclosures
Human subjects: Consent was obtained or waived by all participants in this study. İzmir, Bozyaka Education and Research Hospital Ethical Committee issued approval 04.07.2018-6. Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue. Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work. Financial relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References
1. Ganeshan A, Warakaulle DR, Uneroi R: Central venous access. Cardiovasc Intervent Radiol. 2007, 30:26-33. 10.1007/s00270-006-0021-z
2. Tocino IM, Watanabe A: Impending catheter perforation of superior vena cava: radiographic recognition. Am J Roentgenol. 1986, 146:487-490. 10.2214/ajr.146.3.487
3. Fletcher SJ, Bodenham AR: Safe placement of central venous catheters: where should the tip of the catheter lie? Br J Anaesth. 2000, 85:188-191. 10.1093/bja/85.2.188
4. Sivasubramaniam S, Hiremath M: Central venous catheters: do we need to review practice on positioning? JICS. 2008, 9:228-231. 10.17511/1470808900507
5. Stonelake PA, Bodenham AR: The carina as a radiological landmark for central venous catheter tip position. Br J Anaesth. 2006, 96:535-540. 10.1093/bja/aei510
6. Kim MC, Kim KS, Choi YK, et al.: An estimation of right- and left-sided central venous catheter insertion depth using measurement of surface landmarks along the course of central veins. Anesth Analg. 2011, 112:1371-1374. 10.1213/ANE.0b013e51820902ef
7. Peres PW: Positioning central venous catheters—a prospective survey. Anaesth Intensive Care. 1990, 18:536-539. 10.1177/03100577X901800422
8. Gebhard RE, Szumk P, Pivalizza EG, Melnikov V, Vogt C, Warters RD: The accuracy of electrocardiogram-controlled central line placement. Anesth Analg. 2007, 104:65-70. 10.1213/01.ane.0000250224.02440.1e
9. Amir R, Knio ZO, Mahmoud F, et al.: Ultrasound as a screening tool for central venous catheter positioning and exclusion of pneumothorax. Crit Care Med. 2017, 45:1192-1198. 10.1097/CCM.0000000000002451
10. Ender J, Erodos G, Krohmer E, Olthoff D, Mukherjee C: Transesophageal echocardiography for verification of the position of the electrocardiographically-placed central venous catheter. J Cardiothorac Vasc Anesth. 2009, 23:457-461. 10.1055/s-0028-1083296
11. Kim WY, Lee CW, Sohn CH, et al.: Optimal insertion depth of central venous catheters—is a formula required? A prospective cohort study. Injury. 2012, 43:38-41. 10.1016/j.injury.2011.02.007
12. Kajzar R, Rao MS, Mrinal M: How correct is the correct length for central venous catheter insertion. Indian J Crit Care Med. 2009, 15:159-162. 10.4103/0972-5229.58545
13. Russell WC, Parker JL: Thirteen centimetre central venous catheters, lucky for all?. Anaesthesia. 2003, 58:588. 10.1046/j.1365-2044.2003.02595.x
14. Premuzic V, Perko D, Smiljanic R: The development of central venous thrombosis in hemodialyzed patients is associated with catheter tip depth and localization. Hemodial Int. 2018, 22:454-462. 10.1111/hdi.12662
15. Björkander M, Benzer P, Schött U, Bromän ME, Kander T: Mechanical complications of central venous catheter insertions: a retrospective multicenter study of incidence and risks. Acta Anaesthesiol Scand. 2019, 63:61-64. 10.1111/aas.13214
16. Mamudeep AR, Manjula BP, Dinesh Kumar US: Comparison of Peres’ formula and radiological landmark formula for optimal depth of insertion of right internal jugular venous catheters. Indian J Crit Care Med.
17. Vinay M, Tejesh CA: Depth of insertion of right internal jugular central venous catheter: comparison of topographic and formula methods. Saudi J Anaesth. 2016, 10:255-258. 10.4103/1658-354X.174904

18. Kang M, Bae J, Moon S, Chung TN: Chest radiography for simplified evaluation of central venous catheter tip positioning for safe and accurate haemodynamic monitoring: a retrospective observational study. BMJ Open. 2021, 11:e041101. 10.1136/bmjopen-2020-041101

19. Zhou C, Lu L, Yang L, et al.: Modified surface measurement method to determine catheter tip position of totally implantable venous access port through right subclavian vein. J Vasc Surg Venous Lymphat Disord. 2021, 9:409-415. 10.1016/j.jvsv.2020.07.004

20. Struck MF, Schmidt T, Winkler BE, Reinhart K, Schummer W: Formulas for prediction of insertion depths of internal jugular vein catheters adjusted to body height categories. J Vasc Access. 2016, 17:191-194. 10.5301/jva.5000488

21. Albrecht K, Nave H, Breitmeier D, Panning B, Tröger HD: Applied anatomy of the superior vena cava-the carina as a landmark to guide central venous catheter placement. Br J Anaesth. 2004, 92:75-77. 10.1093/bja/aeh013

22. Dulce M, Steffen IG, Preuss A, Renz DM, Hamm B, Elgeti T: Topographic analysis and evaluation of anatomical landmarks for placement of central venous catheters based on conventional chest X-ray and computed tomography. Br J Anaesth. 2014, 112:265-271. 10.1093/bja/aet341

23. Chui J, Saeed R, Jakobowski L, et al.: Is routine chest X-ray after ultrasound-guided central venous catheter insertion choosing wisely? A population-based retrospective study of 6,875 patients. Chest. 2018, 154:148-156. 10.1016/j.chest.2018.02.017

24. Oulego-Erroz I, González-Cortes R, García-Soler P, et al.: Ultrasound-guided or landmark techniques for central venous catheter placement in critically ill children. Intensive Care Med. 2018, 44:61-72. 10.1007/s00134-017-4985-8

25. Kim SC, Heinez I, Schmiedel A, Baumgarten G, Kneuermann P, Hoeflt A, Weber S: Ultrasound confirmation of central venous catheter position via a right supraclavicular fossa view using a microconvex probe: an observational pilot study. Eur J Anaesthesiol. 2015, 32:29-36. 10.1097/EJA.000000000000042