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Original Article

Comparative Study of Three Methods for Depth of Central Venous Catheter Placement in Children: An Observational Pilot Study

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Abstract

Objective: Central venous cannulation of the internal jugular vein is difficult in paediatric patients because of the small size of the vein and anatomic variations. Many studies have shown the accuracy of various formulae for calculating the depth of placement. The aim of this study was to assess the most reliable method for central venous catheter (CVC) tip placement in paediatric patients.

Methods: Sixty-nine patients in the age groups from 0 to 12 years were divided in three groups for three published techniques for catheter tip placement. In Group E, catheter tip was placed at the distance measured from entry point to sternal angle. In Groups P and H, Peres and trans-oesophageal echocardiography (TEE)-derived formulae, respectively, were used for catheter placement. Post-procedure chest radiograph was performed for all patients, and tip position was recorded. Appropriate catheter tip position was considered just above or at the level of carina. The number of attempts and complications were recorded. Chi-square test was used for statistical analysis.

Results: Of 69 patients, 65% of patients in Group P, 52% in group H and 91% in group E had appropriate CVC tip placement. The chi-square test showed that the difference in the number of patients with appropriately positioned CVC tip among the three groups was statistically significant (p=0.0134), with intergroup analysis showing Group E to be superior. One patient had an episode of arrhythmia during guide wire insertion and was resuscitated successfully.

Conclusion: Catheter tip placement by external distance or landmark technique is a more accurate method for catheter placement than the Peres and TEE-based formulae. It does not require measurement of patients' height and reduces the chances of repositioning of catheter.

Keywords: Landmark technique, central venous catheter, Peres formula

Introduction

Central venous catheters (CVCs) have become ubiquitous in paediatric intensive care setting as well as in the operating room. Central venous catheterisation has been indicated in patients experiencing shock and severe dehydration as well as for long-term parenteral nutrition, central venous pressure monitoring, difficult peripheral venous cannulation and surgeries where major blood loss or fluid shifts are anticipated. The internal jugular vein (IJV) is preferred for cannulation due to its minimal complications and predictable anatomic location. The accurate position of a CVC tip is set at or just above the superior vena cava (SVC)/right atrium (RA) junction to avoid complications such as cardiac perforation, tamponade, arrhythmia, valvular insufficiency, atrial thrombosis and catheter dysfunction (1-3). A chest X-ray (CXR) is often recommended for the confirmation of tip position. Carina is considered as a radiological landmark for accurate catheter tip position (4-6).

Several methods have been proposed to determine the depth of catheter placement on the basis of external landmarks, height-based and trans-oesophageal echocardiography (TEE)-derived formulae (7-10). But there are few studies validating these in the Indian paediatric population (10-12). None of the previously presented methods have been evaluated and tested in a controlled standardised environment (13). Estimation of the optimal length of insertion is complicated by the fact that patients considerably differ in size depending on their age, anthropometry and nutritional status. The height based formulae may not hold true (14). Hence, we conducted a study to assess the efficacy of three methods for accurate CVC tip placement: Peres formula, TEE-derived formula and distance measured externally between entry point and sternal angle.

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Methods

The study (protocol no. EC/OA-26/2015) was approved by the Institutional Ethics Committee (IEC-1) of Seth G.S. Medical college and K.E.M. hospital on 10 July 2015. Informed consent for the study was obtained from parents before enrolling the child for the study along with assent from children older than 7 years. Sixty-nine patients of age from 0 to 12 years requiring central venous cannulation were enrolled in this pilot study. The study was conducted in a tertiary-care government hospital. Paediatric patients from surgical and medical wards, ICU, NICU and operation theatre who required central venous access were included. Central line insertion was performed in the paediatric surgery operation theatre.

From previous studies (14, 15), the proportion of patients with appropriate CVC tip positions was 97% in the TEE-based formula group, 93% in the external landmark group and 74% in the Peres formula group. Assuming power of study as 0.9 and alpha error as 5%, sample size was calculated to be 57. Assuming a dropout rate of 10%, sample size was calculated as 21 in each group i.e. total of 63. Patients with coagulopathy, infection at local site and pre-existing arrhythmias were excluded from the study. Randomisation was conducted using the website www.randomisation.com that generated a plan which divides the patients randomly into three groups. The principal investigator enrolled the participants, whereas an anaesthesiologist not involved in the study assigned the intervention according to the random number table. Sequentially numbered, opaque sealed envelopes technique was used for allocation concealment. The intervention to be performed was concealed till the assignment was irreversibly performed. The patient, the investigator enrolling the participants and the co-investigator collecting the data and analysing it were all blinded to the treatment. Therefore, triple blinding was ensured. For all age groups, the height was measured in the supine position with legs fully extended and head in the midline. The length was measured from the top of the head to the heels of the feet. Height (in cm) was measured up to the first decimal, but it was rounded to the lower number if it was <0.5 cm and to the upper number if it was >0.5 cm. 'X' was considered as depth in cm. The 'X' value was also rounded to the lower number if it was <0.5 cm and to the upper number if it was >0.5 cm. This was done because the markings on the catheter are at every 1 cm. Hence, it would be easier to fix the catheter midway between the two marks, for example, 3.5 cm than at 3.2 or 3.3 cm.

Group P [Peres formula] (8): Catheter insertion depth (X_p)=(height in cm/10).

Group H [TEE-derived formula based on height] (10): Catheter insertion depth (X_h)=1.7+(0.07×height in cm).

Group E [External Landmark technique] (11): Catheter tip distance (X_e)=external distance from puncture site to sternal angle.

Standard monitors such as electrocardiography, non-invasive blood pressure, pulse oximetry and end tidal capnometry were used. Patients were positioned in 15-degree Trendelenburg position, with the head turned to the left side. Selection of catheter size was as per the patient's weight. Different catheter sizes (3, 4 and 5 Fr) were used for patients weighing <5, 5–10 and 10–20 kg, respectively. The length of the 3-, 4- and 5-Fr catheters was 6, 6 and 8 cm, respectively. The CVCs used were manufactured by VygonMulticath 3 (Deutschland, Germany). All catheters were marked with black lines that were separated by 1-cm distance. Patients were anaesthetised using face mask and inhalational Sevoflurane or Ketamine injection to prevent movement and pain during the procedure. All CVCs were inserted using ultrasound guidance. Anaesthesiologists with minimum 1-year experience in paediatric anaesthesia inserted the catheters. Right IJV catheterisation was performed with all aseptic precautions. Puncture was made at the level of the cricoid cartilage for all patients. Once the catheter was sited, as per group allocation, the tip was positioned. For external landmark technique, distance was measured between point of puncture (*I*) and sternal angle (*B*), which was noted as X_e, and catheter was fixed at that distance (Figure 1). For the other two groups, the distance was as calculated from the formulae. After the procedure, confirmation of the tip on the anteroposterior CXR was done. Tip position was deemed appropriate if the catheter tip was just above or at the carina. The catheter tip was repositioned if it was too in or too out and it was recorded as inappropriate. We did not classify the position further as too in or too out. Incidence of complications such as life-threatening arrhythmias, difficulty in advancing guide wire and local haematoma were noted.

Demographic data such as age and weight were analysed using the unpaired t-test, and sex distribution was analysed using the chi-square test. The categorical data, i.e. the number of appropriate and inappropriate positions of catheter, were analysed using the chi-square test. No additional analyses were done. The Bonferroni correction was applied for multiple comparisons. The adjusted alpha value became 0.05/3.

Results

The study was conducted over a period of one year from January 2016 to December 2016. The follow-up period was till 24 h or till CXR was obtained, whichever was the latest.

Data from 69 patients were analysed in this study. There was no significant difference in the demographic profile of the three groups with respect to age, sex and weight (Table 1, p>0.05). Heights ranged between 39 and 135 cm in all groups. The mean height was 77.6 cm, and the standard deviation was 26.19 cm.

The difference between the groups in terms of appropriate placement of the CVC tip was statistically significant (p=0.0134). The chi-square test was significant between groups P versus E and H versus E (p=0.03 and 0.007, respectively). It was not significant between the groups P and H (p=0.35). Of the 23 patients in each group, 15 patients in group P (65%), 12 patients in group H (52%) and 21 patients in group E (91%) showed appropriate tip position (Figure 2). One neonate had severe bradycardia during guide wire advancement, but was successfully resuscitated.

Discussion

Central venous catheterisation in paediatric patients is technically difficult due to the small size of vessels and greater precision required for CVC tip positioning. Tips located near or in the atrium have been associated with a risk of cardiac perforation, tamponade, arrhythmia, valvular insufficiency, atrial thrombosis and catheter dysfunction. The CVC tip has been recommended to be placed just above the SVC/RA junction and pericardial reflection, parallel to SVC, to prevent these complications (1-3). Bedside CXR is still considered the gold standard for identifying catheter malpositions and complications such as pneumothorax (7). On CXR, carina is considered a reliable and simple landmark for the correct placement of CVC tip, because it is at a mean height of 0.4 cm above the pericardial reflection (4-6). There are various formulae to calculate the depth of CVC insertion such as Peres, Andropoluos and TEE-based formulae (8-10). Knowledge regarding the precision of these formulae is scarce and based on only a few studies with low patient numbers. No formula predicts CVC position with sufficient precision (16). The Peres and TEE-based formulae were used because both require height for calculating the depth. Also, calculation by the Peres formula is very easy.

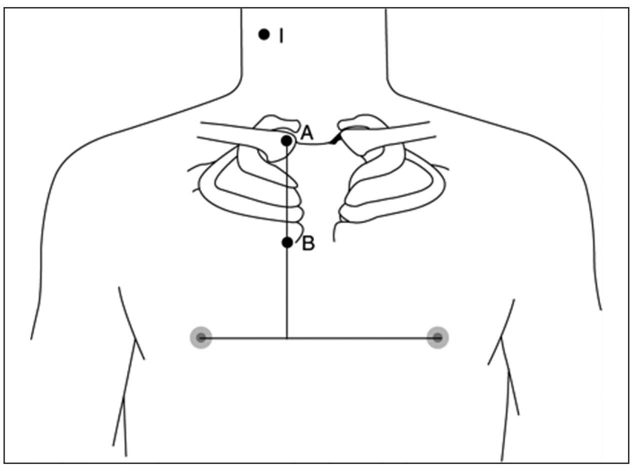

Figure 1. External landmark for group E

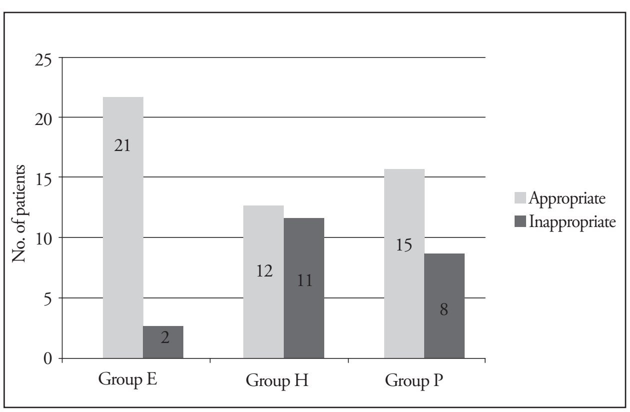

Figure 2. Relative proportions of patients with appropriate and inappropriate positions of CVC tip

In our study, we found that the landmark technique has a better success rate in the appropriate positioning of CVC tip than both the formulae used. The TEE-based formula group had the least success rate. However, we cannot conclusively state that Peres formula is better than TEE-based because the difference was not statistically significant. The external landmark technique has been successfully used in previous studies in paediatric patients (17-20). But it needs to be validated in various racial groups before applying it universally (17). The advantage of this technique is that no sophisticated equipment is required. The length can be adjusted according to the level at which the puncture is made. Height or weight measurements are not required. Other landmarks have been used in previous studies like the third intercostal space and the manubrio sternal joint, but they are comparatively difficult to palpate than the landmarks chosen by us (18, 19).

A study was conducted in 60 right IJV catheterisations in children with heights ranging from 40 to 140 cm that confirmed the tip position using TEE in 2006. The formula was then derived by measuring the distance from the puncture site to the SVC/RA junction (10). They found a good correlation between the distance and height of patients using this formula. However, this formula needs to be validated in the Indian paediatric population. Peres utilised patients' height to develop formulae to predict the optimum length of the catheter to be inserted for right internal or external

Table 1. Demographic characteristics of the three groups

Parameters	Group E	Group H	Group P	Probability
Age in months (Mean±SD)	27.750±0.35	28.27±0.07	27.8±0.28	0.239
Weight in kg (Mean±SD)	10.06±2.2	9.91±2.1	10.10±1.8	0.511
Sex (n) (Male/Female)	15/8	15/8	15/8	1.0000

jugular catheters, right infraclavicular, subclavian catheters and left external jugular catheters. But Peres formula does not take into account the probable differences in catheter insertion length due to variation in same side approach, i.e. high versus cricoid internal jugular approaches (12). A study conducted in 106 adult patients in Seoul in 2012 also concluded that for Asian population, measuring the distance from the insertion point to the SVC/RA junction was more accurate for the placement of CVC tip than the Peres formula (21).

Intra-atrial ECG guidance has also been used to ascertain the CVC tip position outside the RA. However, there were difficulties in the interpretation of the intracavitary ECG in children due to variations and lower voltages of the P waves. Also, it requires specifically designed devices like transducers (Vygocard by Vygon, Alphacard by BBraun) and adaptors (Certodyn, BBraun) (22). Use of ultrasonography has greatly increased the safety of CVCs in children by preventing arterial puncture and confirming endovenous position by the bubble test. However, the exact localisation of the CVC tip in the IJV requires expertise in manoeuvring and positioning the ultrasound probe and interpretation of images.

A limitation of our study is the low sample size, because the study was conducted as a pilot study. A more robust and multicentre trial with a diverse population will enable us to extrapolate the results to the Indian paediatric population. There are various other methods of confirming appropriate positioning of CVC tip such as intra-atrial ECG, TEE and fluoroscopy, but all these are cumbersome and require specialised equipment and expertise.

Conclusion

Our study demonstrated greater success in CVC tip positioning by external landmark technique than by TEE-derived and Peres formulae. Also, because of racial differences in the body habitus, we do not know whether the formulae tested in the Western population will hold true for the Indian population. Further studies to corroborate the findings of this study are required due to the limited sample size.

Ethics Committee Approval: Authors declared that the research was conducted according to the principles of the World Medical Association Declaration of Helsinki “Ethical Principles for Medical Research Involving Human Subjects”, (amended in October 2013).

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