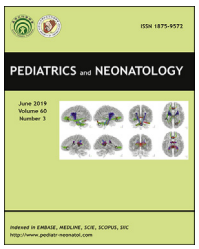
Pediatrics and Neonatology (2019) 60, 305–310

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.pediatr-neonatol.com



Original Article

The equations of the inserted length of percutaneous central venous catheters on neonates in NICU

I-Lun Chen [a,b], Mei-Chen Ou-Yang [a], Feng-Shun Chen [a], Mei-Yung Chung [a], Chih-Cheng Chen [a], Yu-Chen Liu [a], Kuan-Hung Lin [a], Hsin-Chun Huang [a,c,*]

[a] *Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan*
[b] *Graduate Institute of Medicine, College of Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan*
[c] *School of Traditional Chinese Medicine, College of Medicine, Chang Gung University, Linkou, Taiwan*

Received Apr 30, 2018; received in revised form Jun 7, 2018; accepted Jul 27, 2018
Available online 3 August 2018

Key Words
equation;
intensive care;
neonate;
PICC

Background: In neonatal intensive care units, a percutaneous central venous catheter (PCVC) is inserted peripherally and threaded into a central venous location, when intravenous access is anticipated for an extended period of time. The tip location of PCVCs should be checked by an X-ray after the procedure. The present study aimed to determine an equation to estimate the optimal insertion length of PCVCs in neonates prior to the procedure.
Methods: The data of all neonates who had PCVC insertion between May 1st 2015 and April 30th 2016 was reviewed. Their gender, body weight and body length at the insertion date, any complications and the tip culture of their PCVCs were recorded. The tip location of the PCVC, which was confirmed by X-ray, was either in the inferior vena cava near to the diaphragm or in the superior vena cava before the right atrial junction, depending on the insertion site. We analyzed the correlation among inserted length of PCVCs, body weight and body length by linear regression to determine an equation for estimating the optimal insertion length of PCVCs. The accuracy of the equations was evaluated prospectively by Pearson's correlation analysis, and the adjusting rate of PCVCs after the initial insertion was compared between the traditional method and using the equation.
Results: The equation of PCVCs inserted in the foot was "insertion length (cm) $= 16 + 4.27 \times$ body weight (kg)", in the femoral vein was "inserted length (cm) $= 9.8 + 1.7 \times$ body weight (kg)", in the popliteal vein was "inserted length (cm) $= -0.3 + 0.45 \times$ body length (cm)", in the hand was "inserted length (cm) $= 4.46 + 0.32 \times$ body length (cm)", and in the axillary vein

* Corresponding author. Division of Neonatology, Dept. of Pediatrics, Kaohsiung Chang Gung Memorial Hospital, 123, Ta Pei Rd, Niaosung district, Kaohsiung 833, Taiwan. Fax: +886 7 7338009.
E-mail addresses: hhuang@cgmh.org.tw, nbhhuang@icloud.com (H.-C. Huang).

https://doi.org/10.1016/j.pedneo.2018.07.011

was inserted length (cm) = 1 + 0.18 × body length (cm). The adjusting rate of PCVCs after initial insertion was decreased from 73.5% to 53% following use of the equation.
Conclusions: Equations provided a convenient and accurate method to estimate the optimal insertion length of PCVCs before their placement.

1. Introduction

Preterm infants are a special population in today's neonatal intensive care units (NICUs); they often need continuous intravenous catheter placement due to prolonged parental antibiotic treatment, total parenteral nutrition or blood product infusions.[1] However, the placement and maintenance of peripheral intravenous catheters in preterm infants is difficult and can become a challenge for clinicians. An umbilical venous catheter (UVC) is commonly used in the first week after birth as a central catheter in sick infants, however this is typically replaced with a percutaneous central venous catheter (PCVC) for long periods of intravenous catheter maintenance, as the complications of a UVC are closely related to the duration of its use.[2] A PCVC is a catheter in which the tip resides in a central vein via percutaneous insertion from a peripheral vein; it was introduced for the care of preterm infants in 1980.[3] The complications of PCVC placement have been previously reported as infection, thrombosis, phlebitis, bleeding and misplacement.[4] Low-dose continuous infusion of heparin in total parenteral nutrition was previously reported as an effective method of reducing the occurrence of thrombosis.[5] However, heparin may cause intraventricular hemorrhage, which contributes to the majority of mortality and morbidity in neonates weighing <1500 g.[6] The complication rate of PCVCs is associated with the location of their tips. Centrally placed catheter tips are associated with fewer complications compared with non-centrally placed catheter tips.[4] Therefore, the tip location of PCVCs is an important factor in reducing the complication rate of PCVCs. In the present study, the data of all babies who had PCVCs inserted during their hospitalization in the NICU in a medical center in southern Taiwan were evaluated, and an equation was designed to estimate the optimal insertion length of PCVCs at various locations.

2. Material and methods

The authors reviewed the medical records of babies who were admitted to the NICU between May 1st 2015 and April 30th 2016. The Institutional Review Board of Chang Gung Memorial hospital approved the present study. All PCVCs were inserted using a 2 French PER-Q-CATH ® catheter by nurse practitioners and neonatal fellows using the standard method in a sterile environment. The insertion and maintenance of PCVC were performed according to the instructions of the PCVC manufacturer. In the NICU, PCVCs were used for the administration of antibiotics, total parental nutrition and fat emulsion infusion. There were no blood products infused via the PCVCs. The tip location of the PCVCs was into the inferior vena cava near to the diaphragm or into the superior vena cava before the right atrial junction, depending on the insertion site. After the procedure, X-ray films without contrast were performed to check the tip location of the PCVCs (Fig. 1), and a pediatrician used them to determine the PCVC insertion length. All PCVCs were replaced every 3–4 weeks until clinically unnecessary. All removed PCVCs had their tips cultured for bacteria and fungus. The PCVCs were divided into upper and lower extremity groups depending on their insertion sites. The inserted length of the PCVCs was recorded and confirmed by a pediatrician via interpretation of an X-ray. The patients' gestational age, gender, body weight and length at the insertion date, as well as any complications and the results of a PCVC tip culture were recorded. Body length was measured as the crown-heel length. Linear regression was used to determine the association between insertion length, body weight, body length and body mass index (BMI) at the insertion date, to design an equation for estimating the optimal insertion length of PCVCs in neonates. In linear regression, R^2, the coefficient of determination, is a value that calculates how well the regression prediction approximates the real data points. Furthermore, Pearson's correlation analysis was used to evaluate the accuracy of the estimated length of PCVC insertion, as calculated from the equations; the adjustment and complication rates were compared between before and after using the equations.

3. Results

Between May 1st 2015 and April 30th 2016, 240 infants received PCVC placement in the NICU. A total of 26 infants who had PCVCs with a misplaced tip were excluded. These locations of the misplaced tips were artery, upward to head, kinking in femoral vein-inferior vena cava junction and into the peripheral vein. In the remaining 214 babies who were enrolled in the study, 46 were full-term and 168 were preterm; 112 were males and 102 were females. The mean length of PCVC placement was 20.49 ± 10.49 days. Among the 214 PCVCs, 46 were inserted in the upper extremities, (26 were inserted in the hand into the cephalic and dorsal veins, 6 were inserted in the cubital fossa into the median cubital, cephalic or basilic veins, 7 were inserted into the axillary vein, and 7 were inserted in the arm into the cephalic or basilic vein). The mean gestational age of the babies was 31.94 weeks. The mean birth body weight, and mean body weight and body length at

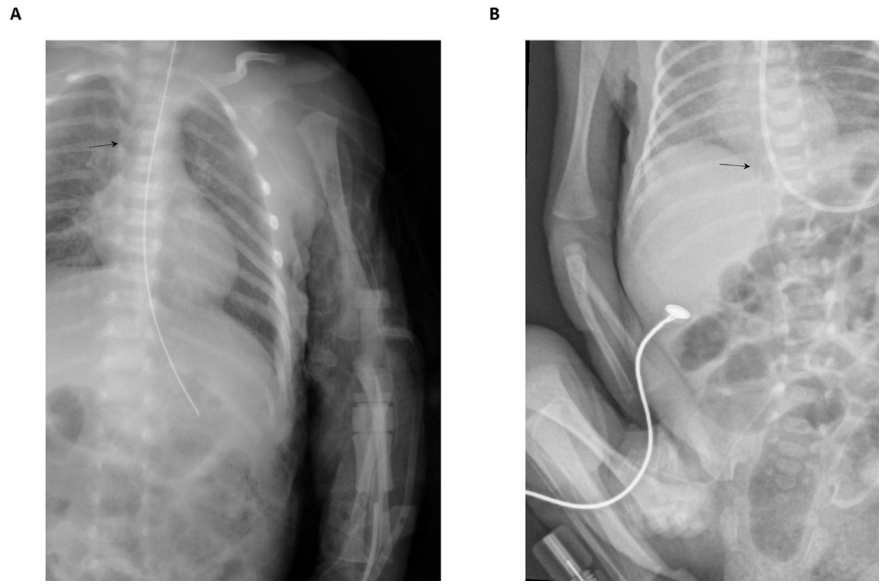


Figure. 1 (A) The tip location of PCVCs in the upper limbs was into the superior vena cava before the right atrial junction, as shown by the arrow. (B) The tip location of PCVCs in the lower limbs was into the inferior vena cava near to the diaphragm, as shown by the arrow.

the insertion date were 1741.13 g, 2407.89 g and 44.22 cm, respectively. The remaining 168 PCVCs were inserted from lower extremities (113 in the foot into the small saphenous or great saphenous veins, 41 into the popliteal vein and 14 into the femoral vein). The mean gestational age of these babies was 31.22 weeks. The mean birth body weight, and mean body weight and body length at the insertion date were 1536.89 g, 1689.16 g and 44.09 cm, respectively. The observed complications of PCVC insertion were occlusion, infection, phlebitis and leaking. The overall complication rate was 30.3%. The tip culture performed on the all 214 PCVCs revealed 23 had positive findings; there were 13 cases of *Malassezia furfur*, 7 of *Staphylococcus* and 3 of yeast. Linear regression was used to develop an equation for each insertion site using the body length, body weight, and BMI; the most significant one was reported according to R^2. In the lower extremities, PCVCs inserted in the foot had an equation of "inserted length (cm) $=$ 16 $+$ 4.27 $\times$ body weight (kg)" ($R^2 = 0.838$). PCVCs in the femoral vein had an equation of "inserted length (cm) $=$ 9.8 $+$ 1.7 $\times$ body weight (kg)" ($R^2 = 0.770$). PCVCs in the popliteal vein had an equation of "inserted length (cm) $=$ $-$ 0.3 $+$ 0.45 $\times$ body length (cm)" ($R^2 = 0.700$). In the upper extremities, PCVCs in the hand into the cephalic and dorsal veins had an equation of "inserted length (cm) $=$ 4.46 $+$ 0.32 $\times$ body length (cm)" ($R^2 = 0.815$). PCVCs in the cubital fossa into the media cubital, cephalic or basilic veins had an equation of "inserted length (cm) $=$ $-$1.45 $+$ 0.36 $\times$ body length (cm)" ($R^2 = 0.994$). PCVCs in the axillary vein had an equation of "inserted length (cm) $=$ 1 $+$ 0.18 $\times$ body length (cm)" ($R^2 = 0.689$) (Table 1). Furthermore, a total of 102 new cases were collected, including 73, 3, 8, 18, 5 and 5 who received PCVC insertion in the foot, femoral vein, popliteal vein, hand, cubital fossa and axillary vein, respectively based on the developed equations. This was performed to determine the accuracy of the equations. Pearson's correlation was used to analyze the correlation between estimated inserted length as determined by the equations and the correct inserted length as confirmed using X-ray films. The Pearson's correlation coefficient of PCVCs in the foot, femoral and popliteal veins, hand, cubital fossa and axillary vein were 0.881, 0.967, 0.937, 0.833, 0.400 and 0.754, respectively (Table 2). After applying the equation, the adjustment rate decreased

Table 1 The equations of inserted length of PCVCs on each site.

Inserted site	Equations	R^2
Foot	16 $+$ 4.27 $\times$ body weight (kg)	0.838
Femoral vein	9.8 $+$ 1.7 $\times$ body weight (kg)	0.770
Popliteal vein	$-$0.3 $+$ 0.45 $\times$ body length (cm)	0.700
Hand	4.46 $+$ 0.32 $\times$ body length (cm)	0.815
Axillary vein	1 $+$ 0.18 $\times$ body length (cm)	0.689

kg $=$ kilogram, cm $=$ centimeter.

Table 2 The correlation of calculated length and corrected length of PCVCs on each site.

Inserted site	Calculated length (cm)	Corrected length (cm)	Pearson's correlation
Foot	23.53 $\pm$ 3.81	23.05 $\pm$ 3.05	0.881
Femoral vein	13.14 $\pm$ 2.43	12.67 $\pm$ 3.78	0.967
Popliteal vein	18.63 $\pm$ 4.93	19.87 $\pm$ 4.90	0.937
Hand	18.84 $\pm$ 2.50	18.67 $\pm$ 4.37	0.833
Axillary vein	7.80 $\pm$ 2.04	8.34 $\pm$ 1.94	0.754

kg $=$ kilogram, cm $=$ centimeter.

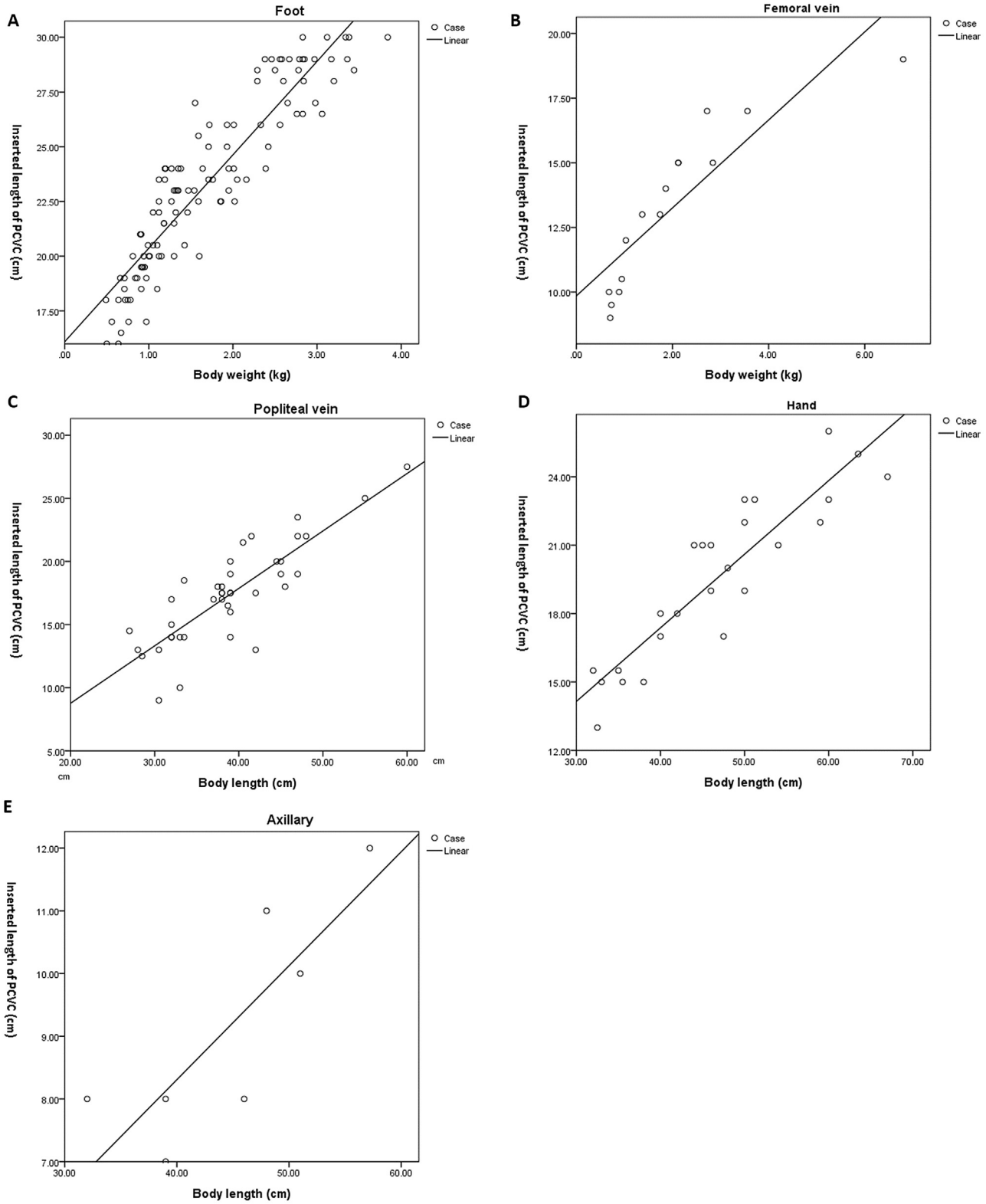


Figure. 2 (A) The inserted length of PCVC in the feet (cm) = 16 + 4.27 × body weight (kg), R = 0.915, P < 0.01. (B) The inserted length of PCVC in the popliteal vein (cm) = 9.8 + 1.7 × body weight (kg), R = 0.878, P < 0.01. (C) The inserted length of PCVC in the femoral vein (cm) = −0.3 + 0.45 × body length (cm), R = 0.837, P < 0.01. (D) The inserted length of PCVC in the hand (cm) = 4.46 + 0.32 × body length (cm), R = 0.903, P < 0.01. (E) The inserted length of PCVC in the axillary vein (cm) = 1 + 0.18 × body length (cm), R = 0.830, P = 0.021.

from 73.5% to 53% ($p = 0.003$) and the complication rate decreased from 30.3% to 24.5%, however it was not significantly different ($p = 0.34$). According to the analysis described above, using the equations for PCVCs on the lower extremities resulted in a better accuracy than the upper extremities. Fig. 2 shows the relationship between PCVCs inserted in the lower and upper extremities, with body weight and length, respectively.

4. Discussion

To the best of our knowledge, the present study was the first to report an equation, which determines the optimal insertion length of PCVCs in neonates. These equations may be used before the procedure to clearly estimate the length of PCVCs which should be inserted. In the past, 73.5% of PCVCs in the author's NICU required adjustment to their insertion length after their location was observed on an X-ray. In the present study, it was found that the adjustment rate decreased to 53% after using the equations prior to the procedure.

PCVC are commonly used on neonates because they are more stable than peripheral catheters and do not need to be replaced as frequently. Therefore, neonates receive less skin punctures, and the experience of PCVC insertion is less painful than peripheral catheters.[7] Ultrasonography has been previously reported to provide precise information regarding the PCVC tip position.[8] However, the body size of premature babies is very small and the ventilators (especially high frequency oscillatory ventilation) are frequently applied to support their immature lung function, so the window of ultrasound may be clinically limited. Therefore, chest X-rays are still used to confirm the position of PCVC tips after their insertion. In the past, prior to insertion the length of PCVCs was estimated from the planned insertion site to the right clavicle head and down to the third intercostal space or to the umbilicus and up to the xiphoid process. However, using this method 73.5% of PCVCs required adjustment following observation of X-ray films. To improve this adjustment percentage, the equations were statistically calculated, the aim was to develop a more accurate and convenient way of estimating the correct insertion length of PCVCs before the procedure, and therefore reduce the adjustment rate. The regression coefficient of these equations was around 0.9, only the PCVCs inserted in the arms had limited correlation. The reasons for this could be that the number of PCVCs inserted in the arms were too small, and the distance from the right or left arms to the superior vena cava were different; therefore, the equations of the right and left upper extremities should be analyzed separately.

There was difference in PCVC-related complications in the upper and lower extremities.[9] In the authors experience, it was preferential to insert PCVCs from lower extremities as complications, such as infection, occlusion, phlebitis and leakage are not life-threatening. However, it was previously reported that for PCVCs inserted in lower extremities, there is a risk the tip may ascend into the lumbar vein and cause the epidural space to fill with parenteral nutrition solution.[10] However, spinal lateral radiography can be used to detect the aberrant location of the tip and prevent this severe complication. In addition, PCVCs inserted in the upper extremities have a risk of cardiac tamponade, pleural effusion and going upward into the head, which is a result of tip migration.[11,12] Therefore, correct catheter tip location is associated with fewer complications.[4] The most common sites selected for PCVC insertion in children are femoral, internal jugular vein and subclavian vein.[13,14] The femoral vein has a higher success rate compared with other sites.[14]

Echocardiography is a more accurate and safer method of tip detection compared with standard radiography,[8] however, the window for echocardiography is very limited in premature babies, especially in those with an extremely low birth weight. In addition, these babies often need an endotracheal tube for ventilation, and their body size and neck are very small, all of which are obstacles for determining the tip location in the suprasternal view of echocardiography. Therefore, radiography is still needed for estimation of the tip location of PCVCs.

5. Conclusions

Equations were determined to estimate the optimal insertion length of PCVCs before performance of the procedure. This novel method could provide a more accurate way of determining the insertion length of PCVCs compared with before, which will reduce the rate of adjustment.

Conflicts of interest statement

The authors declare that they have no potential conflicts of interest, and there was no financial support given for this research, its authorship, and/or publication of this article.

Funding

This study was supported in part by grant CMRPG8D0691-2 (H-C Huang).

Acknowledgements

The authors would like to thank the Biostatistics Center (Kaohsiung Chang Gung Memorial Hospital) for their statistical analysis.

References

1. Wilmore DW, Dudrick SJ. Growth and development of an infant receiving all nutrients exclusively by vein. *JAMA* 1968;**203**:860—4.
2. Junker P, Egeblad M, Nielsen O, Kamper J. Umbilical vein catheterization and portal hypertension. *Acta Paediatr Scand* 1976;**65**:499—504.
3. Puntis JW. Percutaneous insertion of central venous feeding catheters. *Arch Dis Child* 1986;**61**:1138—40.
4. Racadio JM, Doellman DA, Johnson ND, Bean JA, Jacobs BR. Pediatric peripherally inserted central catheters: complication rates related to catheter tip location. *Pediatrics* 2001;**107**:E28.

5. Uslu S, Ozdemir H, Comert S, Bolat F, Nuhoglu A. The effect of low-dose heparin on maintaining peripherally inserted percutaneous central venous catheters in neonates. *J Perinatol* 2010;**30**:794—9.
6. Allen KA. Treatment of intraventricular hemorrhages in premature infants: where is the evidence? *Adv Neonatal Care* 2013;**13**:127—30.
7. Wilson D, Verklan MT, Kennedy KA. Randomized trial of percutaneous central venous lines versus peripheral intravenous lines. *J Perinatol* 2007;**27**:92—6.
8. Ohki Y, Tabata M, Kuwashima M, Takeuchi H, Nako Y, Morikawa A. Ultrasonographic detection of very thin percutaneous central venous catheter in neonates. *Acta Paediatr* 2000;**89**:1381—4.
9. Bashir RA, Swarnam K, Vayalthrikkovil S, Yee W, Soraisham AS. Association between peripherally inserted central venous catheter insertion site and complication rates in preterm infants. *Am J Perinatol* 2016;**33**:945—50.
10. Chedid F, Abbas A, Morris L. Radiographic inguinal curl may indicate paraspinal misplacement of percutaneously inserted central venous catheters: report of three cases. *Pediatr Radiol* 2005;**35**:684—7.
11. Atmawidjaja RW, Azri M, Ismail IH. Cardiac tamponade: a rare but preventable complication of central venous catheter in neonates. *Med J Malaysia* 2016;**71**:147—8.
12. Bashir RA, Callejas AM, Osiovich HC, Ting JY. Percutaneously inserted central catheter-related pleural effusion in a level III neonatal intensive care unit: a 5-year Review (2008—2012). *JPEN J Parenter Enteral Nutr* 2017;**41**:1234—9.
13. Casado-Flores J, Barja J, Martino R, Serrano A, Valdivielso A. Complications of central venous catheterization in critically ill children. *Pediatr Crit Care Med* 2001;**2**:57—62.
14. Karapinar B, Cura A. Complications of central venous catheterization in critically ill children. *Pediatr Int* 2007;**49**:593—9.