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ORIGINAL ARTICLE

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Influence of arm movement on central tip location of peripherally inserted central catheters (PICCs)

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Abstract *Background*: PICCs are increasingly employed in children. Some of their risks relate to the location of the central tip. Despite care when placing lines, they sometimes move. *Objective*: To evaluate the influence of arm movement on the central tip location of PICCs placed in children. *Materials and methods*: The central tip location of PICCs was studied in 85 children, with the arm placed in six positions. The variables of side, vein, site and arm position were examined to measure the direction and range of tip movement. *Results*: The side, site or vein used did not influence the range of movement of the central tip. Change in position of the arm had a significant influence on the central tip location, moving it an average of 2.2 rib spaces, a maximum of 3.5 ribs. Elbow bending and adduction of the arm caused the central tip to move deeper into the chest, compared to when the arm was straight and abducted 90°. *Conclusion*: Arm position is the significant variable influencing PICC movement. Side, site and vein do not influence the range of movement significantly. Most PICCs descend deeper into the chest with arm adduction and elbow bending.

Keywords PICC · Position · Movement · Children

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Introduction

Peripherally inserted central catheters (PICC) have become a well-established means of secure central venous access in children for periods ranging from weeks to months [1–3]. They are usually inserted in the upper extremity. Alternative sites (scalp, leg) are less common. Irrespective of their insertion site, their tip should be central, at or close to the junction of the superior vena cava with the right atrium (SVC-RA) for arm PICCs, and at the IVC-RA junction for leg PICCs [4]. The SVC-RA junction in the majority of children is at the level of T6, below the right main bronchus, with the patient supine on a fluoroscopic image [5]. When placed under fluoroscopic guidance, one of the radiologist's responsibilities is to ensure the tip is central. The optimal location for an arm PICC is said to be at the SVC-RA junction, recognizing that there are inherent problems with both short and long lines [6–9]. Despite care with measuring the PICC at time of insertion, subsequent imaging often shows the tip of the line to be higher or deeper in the chest than is seen at insertion. This movement causes concern for the pediatricians taking care of the child, when on chest radiographs the line appears inappropriately positioned (e.g. low in the right atrium, through the tricuspid valve, or high in the innominate vein). This movement has been the subject of other studies with variable results [4, 10, 11].

The purpose of this study was primarily to evaluate the influence of arm movement on central tip location of PICCs placed in children, and secondarily to see whether any one insertion site was subject to the least amount of movement.

Materials and methods

Research Ethics Board approval was obtained for this study. Signed parental/patient consent was obtained.

This prospective study included 85 children who presented for PICC insertion to the interventional department. In our institution PICCs are placed using US and

fluoroscopic guidance, with the patient supine and the arm abducted usually to 70°–90°, elbow straight . Normally, the central tip location is recorded fluoroscopically with contrast material at the end of the procedure. Contrast material is used to confirm its intravascular venous position in the SVC, to exclude any tiny tip clots that can occur, and to increase the visibility of the catheter when using low-dose pulse fluoroscopy and last image hold. For this study, the side of insertion (right or left) and the vein site (cephalic above or below the elbow, basilic above or below the elbow) were documented. The central tip location was recorded by a last image hold (or an actual exposure) in six arm positions (Fig. 1) as follows:

Position 1:
arm at side, elbow straight
Position 2:
arm at side, elbow bent
Position 3:
arm abducted 90°, elbow straight
Position 4:
arm abducted 90°, elbow bent
Position 5:
arm abducted 180°, elbow straight
Position 6:
arm abducted 180°, elbow bent

The patients were breathing spontaneously as each image was captured, and no attempt was made to control respiration or to capture in either inspiration or expiration. The arm position at time of insertion is usually equivalent to position 3, and this was taken as the baseline position. The recorded images were then printed to hard copy.

The ribs were numbered 1–12 and the interspaces given a value of 0.5. The central tip location of the PICC was given a value according to the level of the rib or interspace on which it projected (Fig. 2). There were, therefore, six values/measurements for each PICC, representing the central tip location in each arm position. The range of motion was documented in units of "rib spaces" rather than in centimeters. This was chosen because of the wide range of sizes of pediatric patients, from premature neonates to full adult size (a 0.5-cm movement might not be significant for an older child, but it is very significant for a neonate). The movement was calculated by the difference in the rib level over which the position of the tip was projected in different arm positions compared to the level of its insertion position (position 3, abducted). The maximum range of movement was calculated as the difference between the highest and the lowest rib level for each PICC.

The two-sample *t*-test was used comparing the range of movement among the sides, sites and veins. A three-way analysis of variance (ANOVA) was performed on all the measurements using SAS version 8.2. Site, side and vein were non-repeating variables. Arm position was a repeating variable (as the central tip location for each PICC was documented in six arm positions). The effect of each variable was examined independently and in combination as type 3 tests to show any complex interaction.

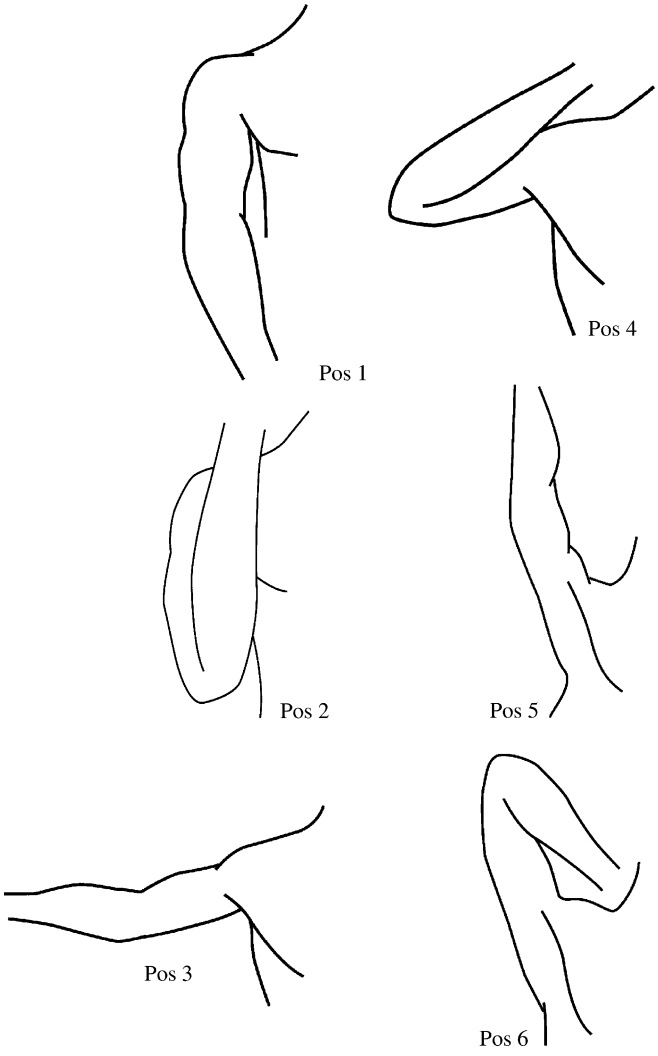

Fig. 1 Schematic representation of the arm positions used to evaluate central tip location of the PICCs

Results

A total of 85 children were studied (33 girls and 52 boys) ranging in age from newborn to 18 years and in weight from 700 g to 61 kg. A variety of PICCs were inserted ranging in size from 3F to 7F, using cuffed and non-cuffed catheters and both single and double lumen. Most PICCs were inserted into the right arm above the elbow (Table 1).

The maximum range of motion of each PICC, as measured by the central tip location in different arm positions, ranged from as little as 0.5 rib spaces to as much as 3.5 rib spaces, with a mean range of movement of 2.2 rib spaces per PICC from the highest recorded tip location to the lowest tip location (Fig. 3).

There was no statistically significant difference between the range or extent of movement of the central tip location when comparing PICCs inserted from the right or left arm ($P \leq 0.89$), from the basilic or the cephalic venous system ($P \leq 0.92$), or from above or below the elbow ($P \leq 0.78$) (Table 2).

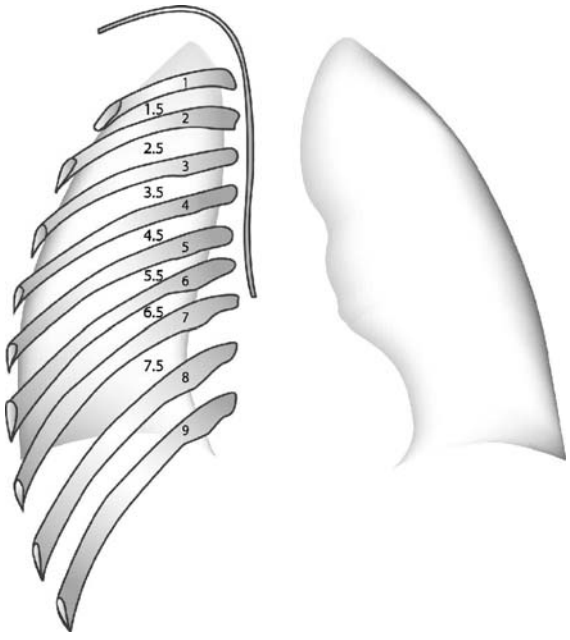

Fig. 2 Schematic representation of ribs and interspaces as numerically assigned with a PICC projected over the seventh rib level

Analysis of the effect of the different arm positions on central tip location showed a statistically significant difference between the average locations of the tip for all sites and both sides as compared to the insertion position (position 3). On average, the central tip descended deeper into the chest (as measured by rib or rib interspace level) with elbow bending and with arm adduction to the patient's side, or abduction of 180°. Thus, the interaction among side, vein and site was not a simple one, as type 3 tests of fixed effects showed the effect of arm position and "site×side×-position" effect to be significant (P<0.006–0.001) but not "site×position" or "side×position" (Table 3). The interaction among these variables was, therefore, quite complex.

On average the insertion position (position 3, abducted 90°, elbow straight) was the shortest (most cephalad) central tip location for all PICC lines. On average, movement of the arm to adduction or to abduction 180°, with or without the action of bending the elbow, caused the central tip location to descend caudally into the chest irrespective of side or site (Fig. 4). The difference in central tip location for all arm positions compared to the location when the arm was abducted elbow straight (insertion position, position 3) was significant when analyzing the entire group except for positions 5 vs. 3 (Table 4).

Table 1 The distribution of the total number of patients (n=85) according to site and side of insertion. The numbers in parentheses are the numbers of measurements recorded per site, as each catheter was examined in six arm positions (if physically possible)

Site of insertion	Left	Right
Basilic vein		
Above the elbow	14 (84)	33 (198)
Below the elbow	7 (42)	19 (114)
Cephalic vein		
Above the elbow	3 (18)	3 (18)
Below the elbow	1 (6)	5 (30)

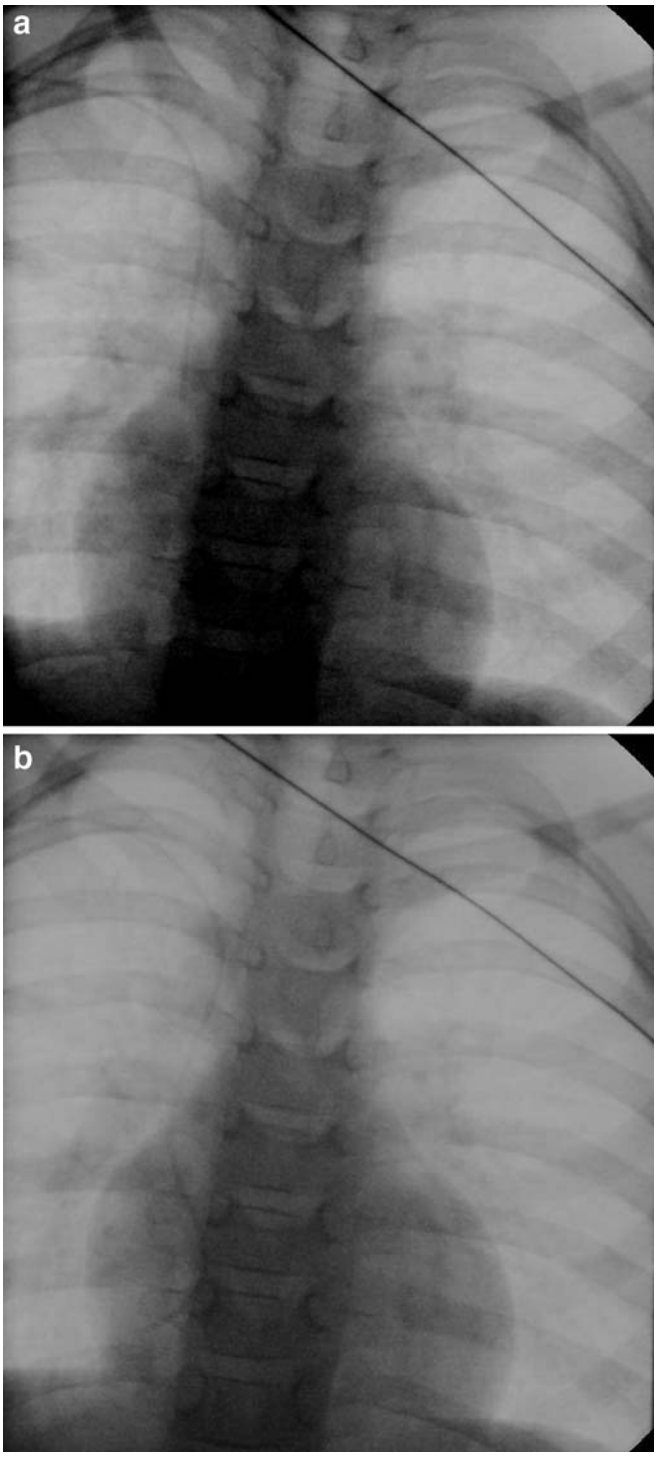

Fig. 3 Fluoroscopic images. **a** Image recorded using last image hold of a PICC line placed from the right arm, with the arm abducted 90° and elbow straight. The tip is at the level of the posterior sixth rib interspace. **b** Image recorded using last image hold of the same PICC line placed from the right arm, with the elbow bent and adducted. The tip is now at the level of the top of the ninth posterior rib

Table 2 This table shows the mean range of motion in units of rib spaces from the shortest to the deepest tip location and compares the differences between right- and left-side PICCs, PICCs inserted in the basilic and cephalic veins, and those inserted above and below the elbow (*NS* not significant)

PICC insertion	No. of measurements available	Range of motion in units of rib spaces		Significance
		Mean	SD	
Vein				
Basilic	73	1.98	0.65	NS (P=0.92)
Cephalic	12	1.95	0.78	
Side				
Right	60	1.96	0.13	NS (P=0.89)
Left	25	1.98	0.087	
Level				
Above	53	1.96	0.69	NS (P=0.78)
Below	32	2.003	0.63	

Discussion

With increasing placement of all types of central venous catheters, the problems of low lines (right atrial perforation, tricuspid valve entrance, arrhythmias) and problems of short lines (stenosis, thrombosis, perforation, flipping, migrating and poor function) are well recognized [4–7, 9, 12–15]. It is also increasingly recognized that the central tip location changes with patient movement [10, 11]. In adult studies on central tip location and movement, change in position is usually evaluated in centimeters. It would be meaningless in a pediatric population to measure the range of motion in such absolute terms as centimeters; therefore, an internal landmark (e.g. rib spaces) was thought to more meaningful. We also thought it would be useful when correlating with the chest radiograph appearances on subsequent imaging.

Exactly why the central tip of the PICC line descends with both adduction and abduction and also with elbow bending is not clear. With adduction of the arm to the patient's side, the length of the axilla is shortened, and in this regard it is analogous to the movement of the endotracheal tube with neck flexion and extension. However, with abduction of 180° it is unclear why it should also descend deeper in the chest from its insertion position, as the soft tissues of the axilla might be considered more stretched. Although the reason is unclear, it might partly explain why in this position (position 5) the range of movement was not significantly different from that in position 3.

Table 3 Relationship between PICC insertion site (cephalic vein above or below the elbow, basilic vein above or below the elbow), side, and position on central tip location. There was no significant effect of insertion side or site on tip location, but there was a significant effect of arm position

Effect	P value
Site	0.172
Side	0.933
Site×side	0.247
Position	<0.0001*
Side×position	0.741
Site×position	0.523
Site×side×position	0.006*

*The effect of arm position on central tip location was significant

The most common/physiological arm position for a child might vary with age, prematurity, intubation, paralysis or other comorbidities. For most children, the arm by the side with slight elbow bending is the most "common/natural/physiological" position, and therefore, if the PICC line is at the SVC-RA junction in these positions (positions 1 and 2), it would suggest that perhaps this would be ideal. This is in contrast to the neonate, who usually lies curled up in the fetal position with the elbow fully bent. When interpreting the chest radiograph the clinician must take into account what position the child was in when the radiograph was taken, as the position is frequently non-physiological. Extrapolating from this, one can only deduce/infer the likely position of the PICC line in the child's natural position. With the infant/child in the "usual/normal" position, the tip might, in fact, be lower or higher than that shown on the radiograph. The vast majority showed the central tip location to be deeper in the chest for all positions other than abduction (position 3). Given the range of movement of PICCs, it must be accepted that the line will not always remain in optimum position. If the line is placed slightly "short", then at times it will be at risk of migrating/flipping into the jugular or innominate vein; if it is placed slightly "long", it might be at risk during some arm movements of traversing the tricuspid valve or descending to the IVC [15].

This study showed that this range of movement occurs whether we use the cephalic or basilic venous system, the left or the right arm, and whether it is inserted above or below the elbow. The majority of our PICCs are usually placed above the elbow, but, interestingly, approximately a third in this study group were placed below the elbow.

Our findings are similar in some respects to those of other authors [10, 11] but differed in that we did not find a difference between cephalic and basilic veins or placement above and below the elbow [10, 11], The study by Nadroo et al. [11] in neonates showed that PICCs placed in the cephalic system moved away from the heart with adduction. Furthermore, though they found those placed below the elbow moved toward the heart with elbow bending, they found those placed in the axillary vein did not move at

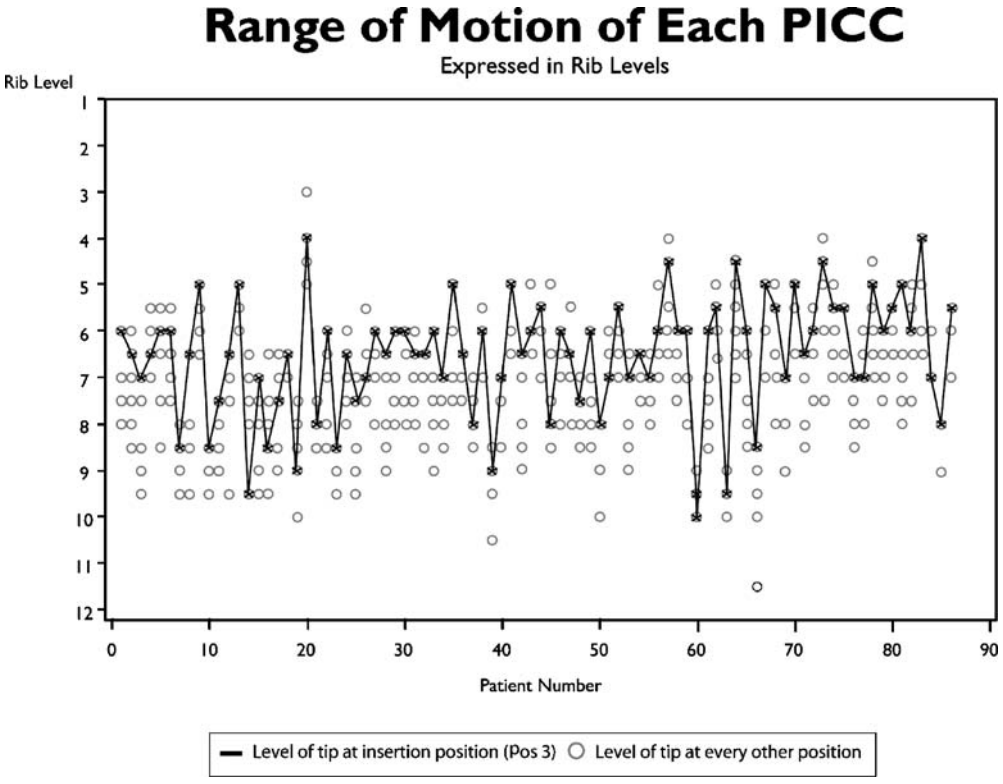

Fig. 4 Rib spaces on the y-axis. Individual patients on the x-axis (n=85). Solid line (*crosses*) is the central tip location in terms of rib level at the insertion position for each patient (position 3). The vast majority of tips descend deeper into the chest (lower rib level) with arm movement, irrespective of side or site of insertion

all with elbow bending. We did not have any placed in the axillary vein itself, but did have many placed in the upper arm above the elbow and found that they, too, moved toward the heart with flexion of the elbow. Like Nadroo et al., we have used this movement of the PICCs to our advantage when trying to reposition a PICC that has migrated; however, we do so under fluoroscopy rather than by a subsequent chest radiograph. The study by Forauer and Alonzo [10] examined similar effects in adults, and with none placed in the cephalic vein or below the elbow. The authors in that study measured the change in tip position in centimeters. They, too, had some PICCs that moved cranially, most moving caudally. There seem to be subtle differences among results from these studies; however, all show that PICCs move, and the majority of movement is toward the heart, with abduction of 90° and elbow straight (position 3, the insertion position) usually being the shortest position.

Table 4 The central tip location as recorded in different arm positions compared to the insertion position showed a significant difference for all positions except abducted 180° with elbow straight (position 5)

	Range of motion in units of rib spaces	Standard error	P value
Position 1 vs 3	0.73	0.101	<0.0001
Position 2 vs 3	1.3	0.1017	<0.0001
Position 4 vs 3	0.76	0.1014	<0.001
Position 5 vs 3	0.10	0.1017	<0.3
Position 6 vs 3	0.58	0.1033	<0.001

Our results point to a complex relationship that might depend on other factors not addressed in this or other studies (e.g. rotation of the shoulder, muscle contraction, etc). The numbers in each group of site insertions (Table 1) were not equal, and this might have influenced the results. Although it would be preferable to have the same number of patients in each group, given the difficulties of PICC placement in small children, we did not want to influence the choice of insertion site in any way to correct for this inequality. Rather, as in real practice, the operator accepts whatever vein site proves possible. However, from these limited results, there does not seem to be one ideal vein site that would result in the least range of motion.

In infants, premature or term, these differences in length between "short" and "long" lines are tiny (<0.5 cm) but still are anatomically important. In neonates, the venous and right atrial walls are very thin and the diameter of the veins very small, rendering the risks of atrial or venous perforation or venous thrombosis high. Following several deaths from atrial perforation from venous lines, a British working party has come out with a statement strongly advising against right atrial tip placement in neonates [16].

The limitations of our study include the fact that we had small numbers overall and fewer in some of our groups as detailed above (few cephalic and few left-side and below the elbow) rendering statistical analysis less powerful. More complex movements were not studied (other than elbow bending, abduction and adduction).

These results suggest that a PICC line inserted in the usual abducted 90° position should be left slightly "short" (at T5 approximately, or right main bronchus), as abducted 90° with elbow straight is the position resulting in the most

cranial central tip location. Thus in a more natural position with the arm adducted with some elbow bending, the central tip location would be lower. We must recognize that even though we take great care to position PICC lines appropriately at the time of insertion, the central tip location subsequently changes as the child moves his or her arm.

Conclusion

PICCs move with arm position; on average they move a range of 2.2 rib spaces (as little as 0.5 rib spaces and up to 3.5 rib spaces). The shortest position is that at the time of insertion, i.e. arm abducted 90°, elbow straight. The choice of insertion side or site does not influence the extent of movement. Interpretation of the position of a PICC on a subsequent chest radiograph must take into account the position of the arm at the time of the radiograph.

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