Malpositioning in blindly inserted PICCs in neonates. Experience in 174 catheters

ROLAND HAASE, CHRISTIAN KUNZE, BEATE WLUDYKA, VOLKER THÄLE, NICK MERKEL

Abstract

Background: Peripherally inserted central venous catheter (PICC) tip mispositioning is associated with increased complication rates. The purpose of this study was to analyze the tip position of blindly inserted PICCs in neonates, and to evaluate factors that influence the rate of correct central positioning. Patients and methods: Over a 29 month period, 691 neonates who were treated in the NICU were analyzed. Catheter tip position was determined by chest X-ray; in cases with questionable positional analysis, sonography or a second X-ray with contrast material was performed. A correct central position was defined as a PICC tip position anywhere in the superior or the upper inferior caval vein. Results: During the study period, 174 PICCs were inserted in 127 neonates. Of these, 111 (63.8%) PICCs were found to have noncentral initial tip positioning. Following correction, 107 (61.5%) PICCs had a correct central tip position. The rate of central positioning was not influenced by gestational age, weight, side (left or right) of insertion, head position, catheter size, mechanical ventilation, or sedation. The rate of correct central positioning was higher when using a lower compared with an upper extremity access ($p < 0.01$). Insertion-related problems were associated with a lower positioning success rate at the initial but not second radiograph ($p = 0.019$). Insertion via the basilic vein was superior to the cephalic vein for achieving correct tip position following correction ($p = 0.027$). Conclusions: In term and preterm infants, correct central positioning of PICCs is possible in most patients, but corrections are often necessary because of initial malpositioning. Further studies are needed to identify strategies to decrease noncentral PICC positions, especially for blind, bedside PICC insertions in neonates.

Key words: PICC, malpositioning, neonate

Introduction

Since their introduction in the early 1970s [1], the use of peripherally inserted central catheters (PICCs) in neonatal intensive care has increased dramatically. The reasons for the growing popularity of PICC are complex. The need for prolonged venous access to administer parenteral nutrition, fluids, and drugs has increased due to improved survival rates of extremely preterm infants. Usually, PICC insertion is simple. PICC-related complications are rare and PICCs are cost effective. Although generally not supported by the manufacturers, PICCs are used occasionally for blood draws, reducing the frequency of painful procedures like heel stick or venipuncture.

Despite the benefits of PICCs, neonatologists and nurses within the NICU must remain aware of possible PICC complications like infection, thrombosis, catheter occlusion, catheter breakage, migration, dysrhythmia, pleural or pericardial effusion, and extravasation [2-6]. A correct central location of the catheter tip may minimize the risk of such complications [7-10]. Dislocation may occur during the overall dwelling time [11], but most malpositionings of the catheter tip are related to the insertion procedure. Many PICCs fail to reach a central position because of the soft nature of the catheter, anatomical variants in vein size, and confluence or possible obstruction from venous valves. Unfortunately, information about the frequency of correct positioning and the circumstances which may influence positioning for neonates are very rare.

To date, it is not clear if several conditions (insertion vein, grade of sedation, head position, mechanical ventilation, weight, and gestational age) may influence the rate of correct catheter tip placement. The aim of this analysis was to identify insertion-related factors which may influence the rate of proper catheter tip positioning and to improve the chance of a correct central position (CCP) of the PICC tip following a blind insertion procedure.
Methods

Patients

The evaluation was approved by our local ethics committee. Data from 691 neonates treated in the Neonatal Intensive Care Unit (NICU) from January 1, 2006 to May 15, 2008 were analysed. The mean gestational age was 35 weeks (range 23-42 weeks, SD 4.2 weeks), and mean weight was 2310 g (range 476-4970 g, SD 954 g). During the study period, a total of 174 PICCs were inserted in 127 neonates. Thirty patients had 2, 4 patients had 3, and 3 patients had 4 PICCs. The number of vein punctures needed to obtain venous access was 1 in 124 of the catheter insertions, 2 in 39 of the catheter insertions, and 3 in 11 of the catheter insertions.

Informed consent for PICC placement was obtained following the insertion procedure in cases with an emergency indication and before placement in all other cases. During the study period, all PICC insertions in neonates were documented. The following data was recorded; medical record number, weight, gestational age, date of PICC insertion, catheter characteristics (size and length), site of insertion, need for mechanical ventilation, patient’s head position, and problems related to the insertion procedure.

PICC placement

PICCs were inserted by or under the supervision of an experienced neonatologist. First, the executing physician identified a peripheral vein suitable for puncture. The choice of catheter was made by the physician inserting the PICC. Normally, the upper limb approach was preferred because of the shorter distance to the caval vein and a supposedly lower rate of catheter related thrombosis. The insertion site was disinfected and covered with sterile tape. The physician and the nurse wore a cap, mask, sterile gown, and sterile gloves. The vein was punctured using a special “Peel away” introducer needle for 2 French (NUTRILINE®, Vygon GmbH, Germany) catheters, or a 24 G needle for 1 French (PREMICATH®, Vygon GmbH, Aachen, Germany) catheters. After puncture, the catheter was inserted blindly through the needle to the previously estimated length. If any difficulty was noted while the PICC was advanced, maneuvers like massaging and moving the extremities or gentle flushing of the catheter in order to assist the catheter passage were allowed.

Position definition

Catheter tip position was determined by chest X-ray and, when in doubt, by sonography or a second X-ray with contrast material. The success of possible tip correction was controlled by a further X-ray. All images were examined by a pediatric radiologist. A CCP was defined as the catheter tip position in the superior caval vein (SCV) after insertion in veins of the upper limb or the head, and in the upper inferior caval vein (ICV) near the diaphragm when the catheter was inserted into veins of the lower limbs. All other positions of the catheter tip were defined as non central positions (NoCP) and divided into near central position (NCP, defined as a catheter tip position in the ipsilateral subclavian vein, the ipsilateral innominate vein, or in the heart) and as malpositions (MP, all other positions of the catheter tip).

Statistical analysis

Patient demographic data and insertion procedure characteristics were collected in a commercially available database (Exel®, Microsoft) and analyzed using the Statistical Package for Social Science, version 15 (SPSS, SPSS Inc., USA). For categorical data, the χ² and the Fisher’s exact test were used. Differences with P-values less than 0.03 were considered to be statistically significant.

Results

During the study period, 127 of the 691 (18.4%) neonates received a total of 174 PICCs. Data were complete for all patients. At initial radiography, CCP was achieved in 63 (36.2%) PICCs, and NoCP in 111 (63.8%). Of the 111 NoCP PICCs at first radiography, 59 (53.1%) were characterized as near central and 52 (46.8%) as malpositioned. Following correction, 107 (61.5%) PICCs had a CCP, 36 (20.7%) a NCP, and 29 (16.7%) PICCs were MP. Catheter removal was necessary in 2 patients. Further details are given in Figure 1. Typical PICC malpositions are shown in Figure 2.

The requirement for a PICC increases with lower weight and shorter gestational age (table 1). Concerning the initial and final central tip location, there were no statistically significant differences between subgroups of different gestational ages or weights (table 2).

A 2-F catheter (length 15 or 30 cm) was used in 99 cases, and an 1-F catheter in 75. Patients with an 1-F-catheter weighed significantly less than those with a 2-F-catheter (mean weight, 1263 ± 746 g versus 2113 ± 933 g, p < 0.03)). The rate of NoCP at first radiography and after correction did not differ between the two catheter groups.

The initial and final tip position was not influenced by noninvasive or invasive mechanical ventilation. In addition, the rate of CCP was not different between patients who were or were not sedated.
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Fig. 1. Detailed position of the catheter tip at first radiography and after correction. On the first radiograph, 3 PICCs in the ICV were inserted from the upper extremity and classified as non central. Other PICC insertion sites on the first radiography (n): axillary vein (7), descending thoracic vein (3), femoral vein (3). Following correction: axillary vein (5), femoral vein (3), removed (2).

Fig. 2. Typical positions of the PICC tip (arrow) defined as non central. In (a), catheter curving back down into the axillary vein after cephalic vein insertion; (b), PICC in the right atrium after upper extremity insertion; (c), PICC in the right atrium after lower extremity insertion; (d), catheter moving across the SCV and going into the subclavian vein; (e), catheter going up the jugular vein after upper extremity insertion; (f), the curving back of the PICC within the inferior caval vein.
Table 1. Gestational age and the need for PICC insertion within the study group

<table>
<thead>
<tr>
<th>Gestational age</th>
<th>Weight ± SD</th>
<th>Patients</th>
<th>Patients with PICC(%)</th>
<th>Number of PICCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 28</td>
<td>899±252</td>
<td>43</td>
<td>32(74)</td>
<td>47</td>
</tr>
<tr>
<td>28-31</td>
<td>1372±326</td>
<td>97</td>
<td>31(32)</td>
<td>41</td>
</tr>
<tr>
<td>32-35</td>
<td>2071±458</td>
<td>217</td>
<td>33(15)</td>
<td>46</td>
</tr>
<tr>
<td>≥35</td>
<td>3118±683</td>
<td>334</td>
<td>31(9)</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 2. Rate of correct central position and factors that may influence the PICC tip position

<table>
<thead>
<tr>
<th>Factors</th>
<th>First radiography (174)</th>
<th>Following correction (172*)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>central position</td>
<td>non central</td>
</tr>
<tr>
<td>Gestational age (weeks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 28</td>
<td>20</td>
<td>27</td>
</tr>
<tr>
<td>28-31</td>
<td>12</td>
<td>29</td>
</tr>
<tr>
<td>32-35</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td>≥35</td>
<td>12</td>
<td>28</td>
</tr>
<tr>
<td>Weight (g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1000</td>
<td>22</td>
<td>25</td>
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<tr>
<td>1000-1499</td>
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<td>27</td>
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<tr>
<td>1500-2499</td>
<td>16</td>
<td>35</td>
</tr>
<tr>
<td>2500</td>
<td>13</td>
<td>24</td>
</tr>
<tr>
<td>Catheter type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-F</td>
<td>27</td>
<td>48</td>
</tr>
<tr>
<td>2-F</td>
<td>36</td>
<td>63</td>
</tr>
<tr>
<td>Mechanical ventilation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>58</td>
<td>88</td>
</tr>
<tr>
<td>no</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td>Sedation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>51</td>
<td>74</td>
</tr>
<tr>
<td>no</td>
<td>12</td>
<td>36</td>
</tr>
<tr>
<td>Insertion site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>arm/head</td>
<td>28</td>
<td>78</td>
</tr>
<tr>
<td>leg</td>
<td>35</td>
<td>33</td>
</tr>
<tr>
<td>Insertion side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>right</td>
<td>32</td>
<td>59</td>
</tr>
<tr>
<td>left</td>
<td>31</td>
<td>52</td>
</tr>
<tr>
<td>Head position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>eyes toward insertion site</td>
<td>10</td>
<td>29</td>
</tr>
<tr>
<td>eyes away from insertion site</td>
<td>12</td>
<td>27</td>
</tr>
<tr>
<td>head in neutral position</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td>Insertion related problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>16</td>
<td>48</td>
</tr>
<tr>
<td>no</td>
<td>47</td>
<td>63</td>
</tr>
<tr>
<td>Insertion vein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>basilic vein</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>cephalic vein</td>
<td>2</td>
<td>12</td>
</tr>
</tbody>
</table>
The majority of PICCs were inserted using an upper extremity or scalp vein (n = 106; 60.9%). A leg or foot vein, usually the great saphenous vein, was used in 68 (39.1%) patients. A CCP was detected in significantly more patients after a lower access at first radiography as well as following correction. The rate of MP following correction did not significantly differ between the upper and the lower access groups (23% versus 12%, p = 0.07). The rate of correct placement was not influenced by the side (right or left) of insertion.

With respect to the subset of 69 PICCs inserted from the elbows, the vein of insertion was associated with CCP following correction, with 21% in the cephalic vein and 55% in the basilic vein (p = 0.027). At first radiography, there was also a tendency favoring the basilic vein (27% versus 14%), but the difference did not reach statistical significance. At first radiography, 3 of 14 PICCs inserted from the cephalic vein reached the SCV or the right atrium compared with 29 of 55 PICCs inserted from the basilic vein (p = 0.037). When the number of reported insertion-related problems was compared, no difference between the cephalic and the basilic vein insertion routes was found.

The influence of head position on the rate of correct catheter tip location was evaluated for the 106 catheters inserted from the upper extremities or a scalp vein. The rate of CCP in patients positioned with their eyes toward the insertion site following correction (67%) was higher than in patients with a neutral head position (43%) or in those with the head positioned with the eyes facing away from the insertion site (46%). The differences did not reach statistical significance.

In 64 (36.8%) PICC insertions, associated problems were reported by the executing physician. The most frequent problem was the inability to further introduce the catheter due to resistance. In 54 (86%) patients, the problem was solved by gentle surface massaging, saline flushing, and / or different passive movement maneuvers of the insertion extremity. At the initial but not at final radiography, the rate of CCP was significantly higher in the subgroup without reported insertion problems compared with the subgroup with reported problems (p = 0.019). The frequency of problems was not influenced by the insertion site or the gestational age or weight, but was higher in the 2-F-catheter group compared with the 1-F-catheter group (43% versus 28%, respectively; p = 0.037).

Discussion

The practice of PICC insertion varies between different countries and affiliations. In German neonatal units, bedside placement by neonatologists followed by radiography is most common. Malpositioning of the catheter usually leads to blind repositioning and a second radiograph.

Generally, PICCs are intended to be positioned in the superior (upper extremity or head access) or inferior caval vein (lower extremity access). Positioning within the right atrium is widely avoided because of the danger of arrhythmia, cardiac perforation, and pericardial tamponade [4, 12-14]. As shown in several studies, central placement of PICCs is associated with a decreased frequency of complications in both adults and children [10, 15]. However, the definition of “central position” remains a matter of debate. Interestingly, a previous pediatric study did not find a higher complication rate in groups having a noncentral position compared with a central PICC tip location [16]. A problem with this analysis was that catheters in the subclavian vein were considered as correctly central. Another pediatric study, which classified catheters in the ICV, SCV, and the right atrium as central, found a higher rate of PICC related complications in cases where the catheter tip was in a noncentral position [7]. In our analysis, only catheter tip positions in the superior or the upper inferior caval vein were considered as correctly central (CCP). Because of the short length of the SCV and the tendency for the catheter tip to migrate in contrast with studies in adults, we did not differentiate between high, middle, and low catheter positions within the SCV.

The most common method of localizing the PICC tip is chest radiography. However, on anterior-posterior chest radiograph, malpositioning of a PICC tip may be overlooked. Lateral radiographies or contrast studies can improve the rate of correct PICC tip localization. Ultrasound, especially contrast ultrasound, may be an alternative to repeated radiographs. One must be aware that malposition-associated complications may occur, even in cases of formerly correctly localized PICC tips, due to catheter migration [3, 11].

Most corrections were required in a catheter position within the right atrium. Nomograms correlating weight, insertion site, and insertion length are needed to minimize this avoidable problem. In accordance with other studies, in our analysis MP of the catheter tip in the internal jugular vein was frequent [8, 17]. Maneuvers like turning the head toward the side of the insertion site and tilting the chin towards the chest are described for adults and older children; but for neonates, studies that evaluate the efficacy of these techniques do not exist. Drawing back may lead to positioning of the catheter tip.
in the subclavian or innominate vein (a position from where the catheter can be used for administration of many medications and isotonic solutions, but not in the same way as a correctly central positioned PICC [16, 18]).

In principle, PICC insertion is possible from every peripheral vein. The main access routes described in the literature are the basilic and cephalic vein, the great saphenous vein, and scalp veins [19]. In accordance with the study by Trerotola et al. [20], the use of the cephalic vein in our patients should have been associated with a significantly higher percentage of malpositioning compared with insertion into the basilic vein. We also noted a tendency toward higher CCP rates in patients with the head positioned with the eyes toward the insertion site. Scalp vein access for PICC insertion was seldom used at our institution, but as reported by other authors, may be useful when there are not suitable extremity veins [19]. The highest proportion of initial CCPs was reached when access through a lower extremity was used. The initial and the final success rates (CCP) were 51% and 77% compared with 26% and 53%, respectively. Despite the higher rate of CCP, generally we prefer not to use the lower access because of an increased risk of thrombophlebitis, thrombosis, and the risk of MP of a PICC in the ascending lumbar vein with possible catastrophic consequences [21-23].

In a previous pediatric study [24], the rate of non-central placement was 21% in a group where a 2-F was used compared with 9% when a 3-F was used, and 3% when a 4-F was used. In contrast, we did not find significant differences between the catheter sizes used regarding the initial and final CCP, and the frequency of insertion-related problems. Similar to our results, differences between left and right-sided upper insertion sites are not reported by other authors [20, 25]. In addition, the risk of malpositioning of the catheter was not significantly influenced by birth weight, gestational age, mechanical ventilation, or sedation.

Most pediatric publications include children of several ages. Studies focusing on term and preterm neonates are rare. An important problem that is especially common in neonates is migration of the catheter tip from the caval veins into the heart or to non-central positions due to normal movements of the extremities [3]. In adults and older children, the tip MP rates range from 0% to more than 30% [7, 10,20, 25-26]. In general, the expectation is that the MP rate is higher in children compared with adults, and higher in neonates compared with older children [27], but the results of published studies are not entirely clear. Chaturvedi examined PICC malpositioning in a large group of pediatric neurosurgical patients. The overall success rate was 49% and the group with the lowest success rate of 9.2% included the youngest children (aged 1 to 5 years). The rate of correct placement was not influenced by sex, side of cannulation, or insertion vein [17]. In contrast, in a study of 587 PICCs in 519 patients, neonates had the highest rate of central placement.

In this study, 47% of PICCs were placed in non-central veins [22, 28]. In another study of 843 insertions, the rate of successful PICC placement under fluoroscopic guidance was 92.5% [27]. In a further study that included pediatric patients, 723 of 843 (85.8%) consecutively placed PICCs had a noncentral position. Of these, 26% of the PICC tips were located in the right atrium, 14% in the brachiocephalic, and 13% in the jugular veins. After repositioning with fluoroscopic guidance, a central tip position was achieved in 760 PICCs (90.2%) [8]. Dubois et al. reported a 96% success rate in children younger than 1 year of age using phlebographic guidance and an insertion site below the elbow [29]. The results of these studies underline the potential role of image guided insertion, but the available techniques are not feasible for use in preterm infants who have a low body weight.

This analysis has several limitations, including the small number of patients and PICCs inserted. In addition, only the completed insertions were included, not all the ones attempted. Insertions through the cephalic vein were often finished prematurely because of the inability to advance the catheter over the confluence of the cephalic and the axillar vein. For this reason, we assume that access via the basilic vein is more advantageous than through the cephalic vein, as demonstrated in our analysis.

In the group of neonates described in our analysis, the initial and final CCP rates were 36.2% and 61.5%, respectively. Because of differences in patient characteristics, types of catheters used, the definition of “central position”, and different veins used for insertion, a comparison with several other PICC studies is difficult [7].

**Conclusion**

The use of PICCs provides feasible, safe, and prolonged venous access in neonates. Despite that proper tip location remains a problem even in neonates, achieving a correct central position is possible in the majority of PICC placements. We generally advocate insertions via the basilic vein with the head positioned so that the eyes are towards the insertion side or via the great saphenous vein to improve the ability to obtain a correct PICC position. However, in daily practice these veins are
often damaged by former attempts to place an intra-
venous catheter and other veins must be used. A limi-
tation of all pediatric PICC studies is that, to date, the
optimal position of the PICC tip is not clearly defined.
For neonates, as well as for older children, further stu-
dies are needed to develop strategies to prevent PICC
MP, especially when the PICC insertion is performed
blind at the bedside.

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