

# Pediatric Peripherally Inserted Central Catheters: Complication Rates Related to Catheter Tip Location

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**ABSTRACT.** *Objective.* To compare complication rates between central venous catheter tip location and noncentral tip location after peripherally inserted central catheter (PICC) placement in children.

*Methods.* Between 1994 and 1998, data from all children who underwent PICC placement were analyzed. Patient demographics, catheter characteristics, catheter duration, infusate composition, and catheter complications were entered prospectively into a computerized database. Catheter tip locations were determined by fluoroscopy and were defined as central if they resided in the superior vena cava, right atrium, or high inferior vena cava at or above the level of the diaphragm, and as noncentral if located elsewhere. Differences in complication rates between the central and noncentral groups were analyzed.

*Results.* Data from a total of 1266 PICCs were analyzed from 1053 patients with a mean age of  $6.49 \pm .2$  years (range: 0–45.0 years). Of the 1266 PICCs, 1096 (87%) were central in tip location, and 170 (13%) were noncentral in tip location. The central group had 42 complications of 1096 catheters (3.8%), while the noncentral group had 49 complications of 170 catheters (28.8%). Controlling for patient age, catheter size, gender, and catheter duration with a logistic regression model, there remained a statistically significant increased likelihood of complication in the noncentral group versus the central group (adjusted odds ratio: 8.28; 95% confidence interval: 5.11–13.43).

*Conclusions.* Centrally placed catheter tips are associated with fewer complications than are noncentrally placed catheter tips. Clinicians should ensure that catheter tips reside centrally after PICC placement in infants and children. *Pediatrics* 2001;107(2). URL: <http://www.pediatrics.org/cgi/content/full/107/2/e28>; *catheters, complications, PICC, central venous, children, infants, phlebitis, occlusion.*

ABBREVIATIONS. PICC, peripherally inserted central catheter; SVC, superior vena cava; RA, right atrium; IVC, inferior vena cava; F, French; OR, odds ratio.

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Peripherally inserted central catheters (PICCs) have become popular in children because they allow safe long-term intravascular access, comfort, and ease of transition to home therapy.<sup>1</sup> A PICC is defined as a catheter inserted percutaneously via a peripheral vein with the tip residing in a central vein. PICCs cannot always be advanced to a central venous location and are occasionally left with the catheter tip in noncentral positions, including the brachiocephalic, jugular, subclavian, axillary, or saphenous veins. There is increasing popularity in placing so-called "midline catheters" or "long IVs" whose catheter tips are intentionally left in a noncentral position.<sup>2</sup> It has been suggested that central catheter tip location is unnecessary for safe intravenous access and infusion of isotonic medications.<sup>3</sup> However, central catheter tip location may very well be important in providing venous access to a region of greater blood flow to achieve effective infusate hemodilution. The concept of rapid hemodilution was a driving force behind the popularization of central venous catheters and is likely to apply to PICCs because similar drugs and solutions are administered through both types of catheters. We hypothesized that central catheter tip location would result in decreased complication rates, compared with noncentral catheter tip location after PICC placement in children.

## METHODS

At Children's Hospital Medical Center, all PICCs are placed by a specialized team of nurses under the supervision of pediatric interventional radiologists. The vast majority of catheters are inserted in the upper extremities at or slightly above the antecubital fossa under direct visualization or palpation of the vein. Ultrasound or contrast venography guidance by a pediatric interventional radiologist is used when veins of adequate size cannot be seen or palpated. After PICC placement, all catheter tip locations are determined by brief fluoroscopy. Catheter tips are defined as central if they reside in the superior vena cava (SVC), right atrium (RA), or high inferior vena cava (IVC) at or above the level of the diaphragm, and as noncentral if located elsewhere. Data regarding patient demographics, catheter characteristics, catheter duration, infusate composition, and catheter complications were entered prospectively into a computerized database. Between 1994 and 1998, data from all children who underwent placement of 2 French (F), 3 F, 4 F, and 5 F BARD (Salt Lake City, UT) Per-Q-Cath single lumen silicone PICCs were analyzed. Complications were recorded including leaking at the PICC insertion site, phlebitis (erythema, swelling, pain, or palpable cord), infection (positive blood and catheter tip cultures), catheter occlusion (inability to infuse or withdraw), and mechanical malfunction (catheter damage or unplanned catheter removal). All complications necessitated catheter removal.

## Statistical Methods

All analyses were performed using *SAS Statistical Software, Version 7* (SAS Institute Inc, Cary, NC). The patients' characteristics and factors related to catheters were examined univariately. For simple comparisons between central and noncentral PICCs, the  $\chi^2$  test and Fisher's exact test were used for categorical data; the 2-sample Student's *t* test was used for continuous variables. To test whether there was a difference in complication rates between the central and noncentral groups, an unconditional logistic regression was conducted. To control for patient age, catheter size, gender, and catheter duration, the adjusted odds ratio (OR) was calculated using multiple logistic regression. Data are expressed as mean  $\pm$  standard error of the mean. Statistical significance is defined as  $P < .05$ .

## RESULTS

Between 1994 and 1998, data from a total of 1266 PICCs were analyzed from 1053 patients with a mean age of  $6.49 \pm .2$  years (range: 0–45.0 years). There were 541 males (51.4%) and 512 females (48.6%). Mean PICC duration was  $15.4 \pm .4$  days (range: 0–106 days). Of the 1266 PICCs, 1096 (87%) were central in tip location (central group), and 169 (13%) were noncentral in tip location (noncentral group). There was no statistically significant difference between the types of infusates administered to the central and noncentral groups (Table 1), with antibiotics being the most common infusate in both groups.

The mean age in the central group was older than that in the noncentral group ( $6.8 \pm .2$  years vs  $4.3 \pm .6$  years;  $P < .01$ ). The mean PICC duration was greater for the central group ( $16.4 \pm .4$  days) than for the noncentral group ( $9.3 \pm .6$  days;  $P < .01$ ). The distribution of catheters by size and tip location is noted in Table 2. The proportions of catheter sizes were different (Fisher's exact test,  $P < .01$ ) between the central and noncentral groups. There was a greater proportion of 2 F catheters in the noncentral group compared with the central group (59% vs 34%, respectively).

The central group had 42 overall complications of 1096 catheters (3.8%), while the noncentral group had 49 overall complications of 170 catheters (28.8%;  $P < .01$ ). Table 3 denotes the differences in specific complications between the central and noncentral groups. Based on the logistic regression analysis, the crude OR is 10.16 with a 95% confidence interval of 6.46 to 15.99 (likelihood ratio test,  $\chi^2 = 93.91$ ;  $P < .01$ ), indicating that the noncentral group was 10 times more likely to develop a complication than the central group.

Considering that complication rates may also be related to other factors, the OR was adjusted for

**TABLE 1.** PICC Infusates in Central and Noncentral Groups

Infusate	Central Tip Location Group	Noncentral Tip Location Group
Antibiotics	993 (90.6%)	156 (91.8%)
TPN	37 (3.4%)	4 (2.4%)
Chemotherapy/antibiotics	18 (1.6%)	1 (.6%)
TPN/antibiotics	15 (1.4%)	4 (2.4%)
Prostaglandins	9 (.8%)	0
None or IV fluids only	24 (2.1%)	5 (2.9%)

TPN indicates total parenteral nutrition; IV, intravenous.

**TABLE 2.** Distribution of Catheters by Size and Tip Location Between the Central and Noncentral Groups\*

PICC Size	Central (n = 1095)	Noncentral (n = 169)
2 F	375 (34.3%)	99 (58.6%)
3 F	662 (60.5%)	68 (40.2%)
4 F	57 (5.2%)	2 (1.2%)
5 F	1 (.1%)	0

\* One patient in each group had no data pertaining to PICC size.

patients' age, catheter size, gender, and catheter duration (Table 4). The adjusted OR is 8.28 (95% confidence interval: 5.11–13.43). Therefore, after controlling for age, catheter size, gender, and catheter duration, the noncentral group was 8 times more likely to have a complication than the central group.

The multiple regression analysis also shows that there was no significant difference in complication rates between 2 F and 3 F catheters. There were 2 PICC infections in catheters whose tips were located centrally and no infections in catheters whose tips were noncentral.

## DISCUSSION

Recognized complications of PICCs include thrombosis, infection, catheter occlusion, phlebitis, chronic venous insufficiency, and pulmonary embolus.<sup>4–8</sup> PICCs cannot always be advanced to a central location for a number of reasons including venospasm, venous tortuosity, and venous valves. There has not been clear evidence in the literature of an association between catheter tip location and complication rates in pediatric PICCs. Our data represent the largest study of PICCs in children and demonstrate that central catheter tip location was an important factor associated with reduced complication rates.

A previous study reported that noncentral tip location was acceptable in children.<sup>3</sup> The investigators examined 587 PICCs, 233 (39%) of which were placed in noncentral veins, and concluded that there was no difference in complication rates between central and noncentral PICCs (27% vs 32%, respectively).<sup>3</sup> However, these authors classified the subclavian vein for catheter tip location as central, and 46% of the central PICCs in that study had catheter tips located in the subclavian vein. In addition, the authors did not address whether the brachiocephalic vein was considered central or noncentral. We define subclavian and brachiocephalic veins as peripheral, and 10 of 49 complications (20%) in our noncentral group occurred in those catheters whose tips were in the

**TABLE 3.** Types of Complications: Central Versus Noncentral Groups

Complication	Central n = 1096	Noncentral n = 170	P Value
Phlebitis	16 (1.5%)	17 (10.0%)	<.001
Occlusion	19 (1.7%)	11 (6.5%)	<.001
Leaking	1 (.1%)	19 (11.2%)	<.001
Mechanical	4 (.3%)	2 (1.2%)	.187
Infection	2 (.2%)	0	1.000
Total	42 (3.8%)	49 (28.8%)	<.001

**TABLE 4.** Multiple Regression Analysis of Complication Rates Between Central and Noncentral Groups Adjusted for Age, Gender, Catheter Size, and Duration

Variable	Adjusted OR	95% Confidence Interval
Noncentral tip location	8.28	5.11–13.43
Age	.97	.93–1.02
Gender	1.49	.94–2.37
Catheter size (2F)	1.16	.24–5.51
Catheter size (3F)	1.56	.36–7.01
Catheter duration	.97	.937–.99

subclavian vein. In our study the complication rate for all PICCs whose tips were in the subclavian vein was 27.8% (10/36).

Studies focusing exclusively on PICCs in children all report success with relatively low complication rates.<sup>3,9–14</sup> Evaluation of investigations concerning the relationship between PICC tip placement and subsequent complications is problematic because of the differences in patient populations including patient ages, diagnoses, insertion techniques, types of catheters, and definitions of central.<sup>3,9–14</sup> Table 5 summarizes 10 recently published PICC articles and their definition of central.<sup>3,6,7,9–12,14,15</sup> Although all studies regard the SVC as central some also include the subclavian and brachiocephalic veins. Our definition of central (SVC, RA, and high IVC at or above the level of the diaphragm) is based on vessel diameters, blood flow estimates, and physiologic flow dynamics. These central locations represent the regions of highest venous blood flow.<sup>16–19</sup>

Studies in adults clearly support the conclusion that central PICC tip location is associated with decreased complication rates.<sup>6,15,20</sup> Kearns et al<sup>6</sup> prospectively analyzed complications associated with PICC tip location in 72 adults and showed an increased risk of thrombosis with peripheral catheter tip location versus central catheter tip location (61% vs 16%;  $P < .05$ ). In a follow-up randomized, controlled clinical trial in 39 adults, these same authors concluded that there was an increased risk of thrombosis of PICCs whose tips were in the axillosubclavian or brachiocephalic veins, compared with the SVC (60% vs 21%;  $P < .05$ ). In addition, catheters associated with thrombosis were more likely to become infected ( $P < .02$ ).<sup>6</sup> A retrospective review of

data from 57 institutions examined the time required to develop a complication in 606 PICCs, comparing central versus noncentral catheter tip position. There were significantly increased rates of extremity inflammation (10% vs 2%;  $P < .05$ ) and shorter median time to complication (30 days vs 223 days;  $P < .05$ ) in catheters placed in a noncentral position.<sup>20</sup> This review lead the National Association of Vascular Access Networks to recommend that “the most appropriate location for the tip of peripherally inserted central catheters (PICCs) is the lower one third of the superior vena cava (SVC), close to the junction of the SVC and the right atrium.”<sup>21</sup>

Decreased complication rates with centrally versus noncentrally located PICC tips is likely related to a combination of factors including vessel size, blood flow rate, turbulent flow, and endothelial injury.

Blood flow rate (volume per unit time) is dependent on diameter, length, and resistance within the vessel. Poiseuille’s law states that the conductance of the vessel increases in proportion to the fourth power of the radius. Thus, slight changes in the radius of a vessel result in large changes in the vessel’s ability to conduct blood. In adults estimated blood flow in the large superficial veins of the upper arm are 10 times less than flow in the SVC.<sup>19,22,23</sup> Smaller vein diameters result in decreased blood flow, causing turbulence and prolonged intimal contact of infusates, which increases the risk of endothelial injury, thrombophlebitis and thrombosis.<sup>5,24–26</sup> Although data pertaining to venous flow characteristics are not available in children, the discrepancy between flow rates is likely greater in children because of their relatively smaller caliber veins.

When a catheter tip is positioned in the subclavian vein, the blood flow and infusate dilution is adequate to administer most drugs and solutions without consequence. However, because flow dynamics in the upper extremity are highly variable in response to physical and environmental changes,<sup>16,18,19</sup> uniform delivery of infusates cannot be guaranteed. Hightower and Gooding<sup>18</sup> sonographically evaluated the physiologic changes in anteroposterior diameter of the subclavian vein in adults in response to various respiratory maneuvers. They demonstrated a wide range (–61% to +21%) of resting mean diam-

**TABLE 5.** Definition of Central in Published PICC Studies

Author	#PICCs	Age (Years)	Central	C Comp %	NC Comp %
Kearns <sup>6</sup>	72	Adults	SVC	16	61
Kearns <sup>6</sup>	39	Adults	SVC	21	60
James <sup>15</sup>	157	1.4–91	SVC	NR	NR
Donaldson <sup>14</sup>	222	0–18	SVC/RA junction	NR	NR
Dubois <sup>10</sup>	285	0–18	SVC/RA junction	NR	NR
Chait <sup>11</sup>	148	0–19	SVC/RA junction	NR	NR
Frey <sup>7</sup>	269	0–27	SVC IVC*	NR	NR
Thiagarajan <sup>3</sup>	587	0–22	SVC RA IVC Subclavian	36	30
Crowley <sup>12</sup>	523	0–18	SVC RA subclavian	NR	NR†
Thiagarajan <sup>9</sup>	441	0–22	SVC RA IVC Subclavian	NR	NR

C Comp indicates central complications; NC Comp, noncentral complications; NR, not recorded.

\* Subclavian and femoral veins “acceptable for antibiotics or nonhyperosmolar solutions.”

† Two episodes of thrombosis occurred with catheters whose tips were in left subclavian/internal jugular vein junction and left brachiocephalic/SVC junction (tip migrating to left internal jugular vein).

eters indicating great potential variability in blood flow rate and volume.

When a central venous catheter tip is positioned in the SVC, the tip is likely to lie parallel to, and not impinge on, the vessel wall. Solutions infused are rapidly diluted in this region. When the catheter tip lies peripheral to the SVC, factors such as venous tortuosity, valves, and decreased vein diameter increase the possibility of tip contact with the vein wall. This contact can disrupt the endothelial cell layer of the tunica intima, exposing the basement membrane, and triggering the clotting process.<sup>27</sup>

### CONCLUSION

Centrally placed catheter tips are associated with fewer complications than noncentrally placed catheter tips. Clinicians should ensure that catheter tips reside centrally after PICC placement in infants and children.

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