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Original Article

Point-of-care Ultrasound for Umbilical Venous and Peripherally Inserted Central Catheterization in Preterm Neonates: A Retrospective Study

Hua Chen[1], Lin Peng[1], Wei Yuan[1], Juan Guo[1], Menghua Chen[1], Rongtian Liu[2]*, Yingying Zhao[1]*

[1]The First Affiliated Hospital of Shenzhen University, Shenzhen Second People's Hospital, Department of Ultrasound Medicine, Shenzhen, Guangdong, China
[2]The First Affiliated Hospital of Shenzhen University, Shenzhen Second People's Hospital, Department of Pediatrics, Shenzhen, Guangdong, China
*Co-corresponding authors

ABSTRACT

Aim: Central venous access in preterm neonates is commonly established with umbilical venous catheters (UVCs) or peripherally inserted central catheters (PICCs). However, landmark-based methods often result in malpositioning and complications. This study aimed to evaluate whether point-of-care ultrasound (POCUS) guidance improves initial tip placement accuracy and reduces subsequent clinical outcomes.

Materials and Methods: This retrospective study included preterm neonates (<37 weeks) who underwent UVC or PICC insertion between March 2023 and April 2024. The neonates were grouped by guidance modality: POCUS vs. non-POCUS (conventional landmark and length-based estimation). The primary outcome was optimal tip placement immediately after insertion [UVC: inferior vena cava (IVC)- right atrium (RA) junction; PICC: superior or IVC near the RA], verified by ultrasound or radiography. Secondary outcomes included complications occurring ≥24 hours after insertion, including malposition, infection, thrombosis, and gastrointestinal complications). Continuous and categorical variables were compared using t-tests or Mann-Whitney U tests and chi-square tests, respectively. Two-sided $p<0.05$ was considered statistically significant.

Results: Among 101 neonates (UVC n=55; PICC n=46), the overall optimal tip placement occurred in 64 cases (63.4%). Placement success was significantly higher with POCUS than with non-POCUS guidance: 29/33 (87.9%) vs. 35/68 (51.5%). UVC placement success was 84.2% in the POCUS group versus 47.2% in the non-POCUS group [odds ratio (OR): 5.96; 95% confidence interval (CI): 1.49-23.91]. PICC placement success was 92.9% versus 56.3%, respectively (OR: 10.11; 95% CI: 1.16-88.01). Total complication rates were significantly lower with POCUS for both UVC (OR: 0.24; 95% CI: 0.07-0.88) and PICC (OR: 0.13; 95% CI: 0.02-0.70), driven by low occurrences in gastrointestinal complications and infections.

Conclusion: In preterm neonates, POCUS guidance improves initial catheter tip positioning and it is associated with fewer complications. These findings support the integration of POCUS into routine neonatal vascular access workflows and warrant validation in prospective studies.

Keywords: Point-of-care ultrasound, umbilical venous catheter, peripherally inserted central catheter, preterm neonates

Corresponding Authors
Rongtian Liu, MD, The First Affiliated Hospital of Shenzhen University, Shenzhen Second People's Hospital, Department of Pediatrics, Shenzhen, Guangdong, China; Yingying Zhao, MD, The First Affiliated Hospital of Shenzhen University, Shenzhen Second People's Hospital, Department of Ultrasound Medicine, Shenzhen, Guangdong, China
E-mails: liurongtian7878@163.com - 704379403@qq.com **ORCIDS**: orcid.org/0009-0000-3680-0382 - orcid.org/0009-0002-9181-2057
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Introduction

Establishing reliable intravenous access is essential in neonatal intensive care for administering medications, fluids, and parenteral nutrition. In preterm neonates, the fragility and small caliber of peripheral veins make cannulation difficult and increase the risk of extravasation, edema, tissue injury, and pain. As a result, central venous access, most often via umbilical venous catheters (UVCs) or peripherally inserted central catheters (PICCs), is commonly used to provide stable, long-term access.

UVCs provide emergency access through the umbilical stump, while PICCs enable central venous access via a peripheral vein (1,2). Both approaches reduce repeated venous punctures, minimize pain for neonates, and reduce the workload for practitioners, helping maintain stable blood oxygen levels and improving survival rates in preterm neonates (1,2).

However, determining the appropriate insertion length and achieving an optimal tip position can be challenging in small neonates. Conventional landmark-based methods are widely used, but they are prone to malpositioning and repeated repositioning, prolonged procedure durations and increased complication risks (1-4).

Post-insertion imaging is essential in order to verify the catheter tip position. Radiography is widely used but offers only a static snapshot and may fail to detect catheter migration. Repeated radiographic examinations also delay clinical decision-making and expose neonates to additional radiation. Ultrasound, by contrast, allows real-time, bedside visualization of catheter advancement and tip position and also allows for the detection of catheter migration associated with neonate positioning or limb position (5-7). In recent years, point-of-care ultrasound (POCUS) has become an accessible, portable tool for procedural guidance and catheter verification. However, evidence specific to UVC and PICC placement in preterm neonates remains limited.

This study aimed to evaluate whether POCUS guidance improves the accuracy of UVC and PICC tip placement and reduces complications when compared with conventional methods in preterm neonates.

Materials and Methods

Study Design and Participants

This retrospective study included 101 preterm neonates who underwent central venous catheterization in neonatal intensive care units (NICUs) between March 2023 and April 2024. Eligible infants were <37 weeks' gestation and required UVC or PICC for clinical indications (e.g., respiratory distress, the need for prolonged parenteral nutrition, or hyperosmolar/irritant infusions). In order to allow for adequate surveillance monitoring of post-procedural complications, catheters which remained in place for <1 week were excluded. This study was approved by the review opinion of the Clinical Research Ethics Committee of Shenzhen Second People's Hospital (approval number: 2024-369-01PJ, date: 11.11.2024). Consent was waived due to the retrospective design of this study.

Neonates were grouped by catheterization method: POCUS-guided (POCUS) versus conventional (non-POCUS). Assignment to the POCUS group depended on the availability of a radiologist at the bedside when central access was required. When a radiologist was unavailable, catheterization was performed using conventional methods by NICU nurses in order to avoid delays in treatment.

Demographic variables, including sex, postnatal age, gestational age (GA), and birth weight, were retrieved from the electronic medical record. In the POCUS group, catheter placement was performed by a radiologist with over three years of experience using the MyLab seven (Esaote, Genoa, Italy) ultrasound device, equipped with a 9-12 MHz linear array probe. In the non-POCUS group, catheter insertion was performed by two NICU nurses with over two years of experience using conventional landmark- and formula-based estimation methods.

UVC and PICC Placement

For UVCs, in the POCUS group, the UVC tip was guided to the inferior vena cava (IVC) right atrial (RA) junction. If necessary, a small volume (0.5-2 mL) of normal saline was used to enhance tip visualization. In the non-POCUS group, insertion length followed the modified Shukla formula based on anatomical landmarks: (3×birth weight in kg+9)/2+1 cm (3).

For PICCs, in the POCUS group, the PICC tip was guided to the junction of the superior vena cava (SVC) or IVC near the RA junction. Similarly, normal saline was injected as needed for visualization. In the non-POCUS group, the conventional method was used, estimating insertion length based on anatomical landmarks (4).

Tip Verification

After placement, all neonates underwent ultrasound examination and thoracoabdominal radiography in order to verify the catheter tip position (Figure 1). Optimal tip positions were defined as: UVC tip at the IVC-RA junction, approximately 0.5-1.0 cm above the diaphragm; PICC tip in the SVC or IVC near the RA junction (7-11).

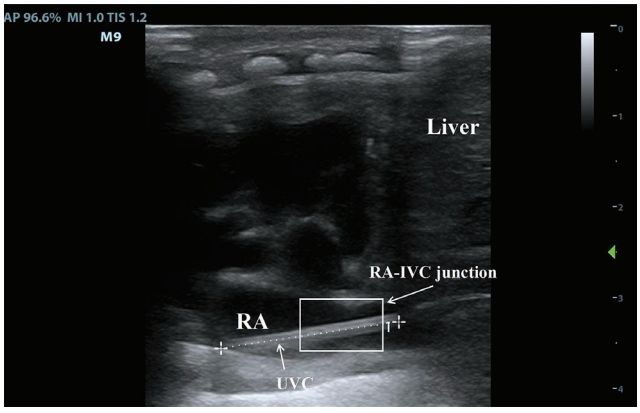

Figure 1. A POCUS scan was conducted to confirm the position of the umbilical venous catheter (UVC) tip after insertion. The tip is seen to be at the junction of the inferior vena cava (IVC) and the right atrium (RA), representing the optimal zone

Outcomes

The primary outcome was the success rate of optimal catheter tip placement immediately after insertion, as confirmed by ultrasound or radiography. Placement failure included the inability to position the catheter tip within the predefined optimal zone. Secondary outcomes were complications occurring ≥24 hours after insertion: malposition, necrotizing enterocolitis (NEC), gastrointestinal complications (e.g., bowel bleeding, distention), pleural effusion, pulmonary hemorrhage, infection, limb swelling, and venous thrombosis. NEC was diagnosed based on the modified Bell's staging, requiring at least Stage II (12). Gastrointestinal bleeding was identified by the presence of gross blood in gastric aspirates or stools, or a positive fecal occult blood test. Bowel distention was defined as a persistent increase in abdominal girth accompanied by radiographic evidence of bowel dilation (11). Infection was defined as a positive blood culture obtained from a peripheral vein or the catheter hub in a symptomatic infant, where no other source of infection was identified. Venous thrombosis was defined as the presence of an echogenic intraluminal mass in a vessel associated with the catheter confirmed by ultrasound.

Statistical Analysis

Continuous and categorical data are presented as means ± standard deviation and frequency (percentage), respectively. Normality was evaluated with the Kolmogorov-Smirnov test. Inter-group comparisons were performed using Student's t-tests or Mann-Whitney U tests for continuous variables and chi-square tests for categorical variables. In order to assess the clinical relevance and magnitude of the effect of POCUS guidance, effect sizes were expressed as odds ratios (OR). Two-sided $p<0.05$ was considered statistically significant. All analyses were performed using SPSS software (version 26, Chicago, IL).

Results

Among the 101 neonates included in this study, 55 underwent UVC insertion, and 46 underwent PICC insertion. Of the UVC cases, 19 were in the POCUS group and 36 in the non-POCUS group. Of the PICC cases, 14 were in the POCUS group and 32 in the non-POCUS group. Baseline postnatal age, GA, and birth weight did not differ significantly between groups for either UVC or PICC (Table I).

The overall success rate of optimal catheter tip placement was 63.37% (64/101). Placement success was significantly higher in the POCUS group than in the non-POCUS group: 87.9% (29/33) vs. 51.5% (35/68). Specifically, for UVC, the POCUS-guided success rate was 84.2% compared with 47.2% in the non-POCUS group [OR: 5.96; 95% confidence interval (CI): 1.49-23.91]. For PICC, the POCUS group achieved a 92.9% success rate, while the non-POCUS group had a 56.3% success rate (OR: 10.11; 95% CI: 1.16-88.01) (Table II).

After insertion, UVC malposition occurred in 22/55 (40.0%), with tips located in the RA (4/22, 18.2%), ductus venosus (8/22, 36.4%), umbilical vein (9/22, 40.9%), and

Table I. Comparison of demographic data for UVC and PICC insertions between the POCUS and non-POCUS groups

	UVC			PICC		
	POCUS group (n=19)	**Non-POCUS group (n=36)**	**p value**	**POCUS group (n=14)**	**Non-POCUS group (n=32)**	**p value**
Sex (Male), n (%)	9 (47.4)	19 (52.8)	0.78	12 (85.7)	22 (68.8)	0.40
Postnatal age (hours)	20.9±12.4	22.3±13.1	0.09	184.3±77.8	139.3±76.2	0.32
GA (days)	220.3±16.0	221.8±18.5	0.76	217.1±19.9	221.8±19.0	0.55
Birth weight (grams)	1,549.0±405.5	1,554.3±508.2	0.97	1,360.0±263.9	1,512.2±406.0	0.38

UVC: Umbilical venous catheters, PICC: Peripherally inserted central catheters, POCUS: Point of care ultrasound, GA: Gestational age

right intrahepatic portal branch (1/22, 4.5%). For PICC, malposition occurred in 15/46 (32.6%): RA 9/15 (60.0%), subclavian 3/15 (20.0%), jugular 2/15 (13.3%), and iliac 1/15 (6.7%). No instances of RA placement were observed in the POCUS group for either catheter type (Table SI).

Post-insertion complications (≥24 hours) were less frequent in the POCUS group. For UVCs, complications occurred in 23/55 (41.8%): 4/19 (21.1%) in the POCUS group versus 19/36 (52.8%) in the non-POCUS group (OR: 0.24; 95% CI: 0.07-0.88) (Table III). Significant differences were observed for gastrointestinal bleeding and bowel distention.

For PICCs, complications occurred in 20/46 (43.4%): 2/14 (14.3%) in the POCUS group versus 18/32 (56.3%) in the non-POCUS group. Although the overall complication rate showed marginal statistical significance (p=0.08), the effect size demonstrated a strong clinical protective trend (OR: 0.13; 95% CI: 0.02-0.70), indicating an 87% reduction in the odds of adverse events under ultrasound guidance. Notably, PICC-related infections occurred in five neonates in the non-POCUS group and in none of the neonates in the POCUS group (p=0.04) (Table III).

Table II. Proportion of successful and failed UVC and PICC in optimal tip placement between the POCUS and non-POCUS groups

	UVC				PICC			
Outcome	**POCUS group (n=19)**	**non-POCUS group (n=36)**	**Odds ratio (95% CI)**	**p value**	**POCUS group (n=14)**	**non-POCUS group (n=32)**	**Odds ratio (95% CI)**	**p value**
Success, n (%)	16 (84.2)	17 (47.2)	5.96 (1.49-23.91)	0.008	13 (92.9)	18 (56.3)	10.11 (1.16-88.01)	<0.001
Failure, n (%)	3 (15.8)	19 (52.8)			1 (7.1)	14 (43.8)		

UVC: Umbilical venous catheters, PICC: Peripherally inserted central catheters, POCUS: Point of care ultrasound, CI: Confidence interval

Table III. Comparison of postoperative complications following UVC insertion between POCUS and non-POCUS groups

	UVC				PICC			
Complications n (%)	**POCUS group (n=19)**	**non-POCUS group (n=36)**	**Odds ratio (95% CI)**	**p-value**	**POCUS group (n=14)**	**non-POCUS group (n=32)**	**Odds ratio (95% CI)**	**p-value**
Necrotizing enterocolitis	1 (5.3)	1 (2.8)	-	1.00	-	-		-
Gastrointestinal bleeding	2 (10.5)	13 (36.1)	0.21 (0.04-0.98)	0.043	2 (14.3)	4 (12.5)	1.17 (0.18-7.53)	0.87
Bowel distention	1 (5.3)	8 (22.2)	0.19 (0.02-0.99)	0.047	0	4 (12.5)	-	0.08
Pleural effusion	0	1 (2.8)	-	1.00	-	-	-	-
Pulmonary hemorrhage	0	1 (2.8)	-	1.00	-	-	-	-
Infection	-	-	-	-	0	5 (15.6)	-	0.04
Limb swelling	-	-	-	-	0	3 (9.4)	-	0.13
Venous thrombosis	-	-	-	-	0	2 (6.3)	-	0.22
Total complications	4 (21.1)	19 (52.8)	0.24 (0.07-0.88)	0.023	2 (14.3)	18 (56.2)	0.13 (0.02-0.70)	0.08

UVC: Umbilical venous catheters POCUS: Point of care ultrasound, PICC: Peripherally inserted central catheters, CI: Confidence interval

Discussion

In this retrospective study, POCUS guidance was associated with improvements in optimal tip placement rates for both UVCs and PICCs and reductions in post-insertion complications when compared with conventional landmark-based methods. These findings are consistent with previous studies showing that real-time ultrasound improves initial positioning accuracy and reduces the need for repositioning and repeated radiographic confirmation.

Correct catheter tip placement is clinically important as malposition can contribute to organ injury, thrombosis, feeding intolerance, and infection. Early UVC placement, ideally performed immediately after birth, has been reported to achieve a higher success rate (13). However, anatomical differences among neonates, particularly in the umbilical vein pathway and the relationship between intrahepatic vessels and the IVC, increase the risk of catheter mispositioning when performed without guidance (14). Visualization challenges in very small peripheral veins further complicate PICC placement (15).

POCUS offers real-time, radiation-free visualization during catheter advancement and tip positioning, potentially reducing repeated manipulations and radiographs (7,8,16,17). In our study, POCUS increased the UVC placement success from 47.2% to 84.2% and PICC placement success from 56.3% to 92.9%. These results are consistent with previous studies which have supported POCUS guidance for neonatal central access (7,18,19). The high success rates associated with POCUS may be attributed to its ability to provide direct visualization and real-time monitoring of catheter placement.

Post-insertion complications such as malposition, infection, NEC, bleeding, thrombosis, and pleural/pericardial effusion are common with neonatal UVC and PICC insertions (1,2,20,21). In this study, 3.6% of neonates developed NEC after UVC insertions, while Sulemanji et al. (20). reported a 1.9% rate of NEC after insertions. This discrepancy may be due to the more frequent malpositioning in the non-POCUS group, as malposition is associated with mesenteric venous ischemia and NEC development (20).

Gastrointestinal bleeding was also more frequent in the non-POCUS group than in the POCUS group (36.1% vs. 10.5%). This may be due to increased vessel wall damage during blind insertion techniques, potentially contributing to the development of thrombosis and subsequent bleeding (22-24). Bowel distention, although often regarded as a secondary manifestation rather than a primary endpoint, was also more common in the non-POCUS group in our study. Since distention can reflect downstream complications (e.g., thrombosis or malposition-related perfusion issues), prompt reassessment of the catheter position is prudent when it occurs after insertion (25-27).

Catheter-related infection is another common complication of UVC and PICC insertion. We observed five infections in the non-POCUS PICC group and none in the POCUS group. This difference may reflect longer PICC usage durations and greater illness severity rather than the guidance modality alone. Oleti et al. (28), reported more cases of infection in the ultrasound-guided group compared to the conventional group. They explained that this might have been due to the longer time required for PICC insertion with ultrasound. Together, these mixed findings underscore the importance of standardized POCUS training in neonatal catheterization in order to minimize complications.

This study had several strengths, including its focus on a critical and vulnerable population of preterm neonates, explicit definitions of optimal tip positioning, and uniform post-procedure imaging. Additionally, the retrospective design allowed us to comprehensively compare outcomes between POCUS-guided and conventional catheter placement, providing valuable insights into the benefits of POCUS in clinical practice.

Study Limitations

The study also had limitations. Its retrospective design may have introduced selection bias as the choice of catheterization method was not randomized. Although baseline characteristics did not differ significantly between the groups, we cannot entirely rule out unmeasured confounding factors. Additionally, this study did not account for operator expertise, which could have influenced success rates and complication incidence rates. Future studies should compare outcomes among operators with similar levels of clinical experience to more accurately quantify the specific benefits of ultrasound guidance in neonatal vascular access. Finally, this study did not explore long-term outcomes or time-to-event endpoints (e.g., infection per 1,000 catheter-days), which could provide additional clinical context.

Conclusion

POCUS guidance for UVC and PICC placement in preterm neonates significantly improves optimal tip positioning and reduces complication rates, including gastrointestinal bleeding and infection. These findings support the integration of POCUS into routine NICU vascular access workflows, alongside structured competency-based training and standardized real-time tip verification procedures.

Future prospective studies should evaluate long-term outcomes, infection rates normalized to catheter-days, and standardized training curricula in order to optimize safety and effectiveness.

Ethics

Ethics Committee Approval: This study was approved by the review opinion of the Clinical Research Ethics Committee of Shenzhen Second People's Hospital (approval number: 2024-369-01PJ, date: 11.11.2024).

Informed Consent: Consent was waived due to the retrospective design of this study.

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Footnotes

Authorship Contributions

Surgical and Medical Practices: H.C., J.G., R.L., Y.Z., Concept: H.C., L.P., W.Y., J.G., M.C., R.L., Y.Z., Design: H.C., L.P., W.Y., J.G., M.C., R.L., Y.Z., Data Collection or Processing: H.C., L.P., W.Y., Y.G., M.C., Analysis or Interpretation: H.C., L.P., W.Y., R.L., Y.Z., Literature Search: H.C., L.P., W.Y., J.G., M.C., Writing: H.C., R.L., Y.Z.

Conflict of Interest: The authors declare no conflict of interest.

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Supplementary Table SI Links: https://d2v96fxpocvxx.cloudfront.net/bb2eeae3-0e60-42a4-acea-81e4a349912c/content-images/d094519c-64ca-4199-8026-e7ac9bf22b2a.pdf

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