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Real-Time Insight: Pocus Integration for Optimal Umbilical Vein Catheterization

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ABSTRACT

Background: *Among the most essential procedures in Neonatal Intensive Care Units (NICUs) is Umbilical Vein Catheterization (UVC), which provides a reliable route for administering life- saving treatments. Point-of-Care Ultrasound (POCUS) is a transformative imaging modality that has redefined procedural accuracy and safety in neonatal care. Existing literature often focuses on procedural time or radiation exposure, without providing a comprehensive evaluation of its impact on success rates and complication reduction. This gap underscores the need for focused studies that assess the effectiveness of POCUS-guided UVC in improving procedural outcomes and neonatal safety.*

Aim: *To evaluate the effectiveness of Point-of-Care Ultrasound (POCUS) in guiding umbilical vein catheterization (UVC) by assessing its impact on reducing complications and improving procedural success rates in neonates.*

Method: *A single center, hospital-based comparative, prospective observational study, conducted in the Level IIIA NICU accredited by the National Neonatology Forum (NNF) at Shri Shishu Bhawan Super Speciality Hospital for Children and Newborn, Bilaspur, Chhattisgarh from January 2024 to December 2024. A total of 180 participants were enrolled in the present study. Ninety neonates in POCUS-Guided UVC group underwent UVC under real-time guidance using POCUS. Remaining ninety neonates in Conventional UVC group underwent UVC using the traditional anatomical landmark-based approach without ultrasound guidance. Neonatal outcomes and any adverse events were recorded on the data collection proforma.*

Results: *The mean time required for catheter placement was significantly lower in the POCUS-guided UVC group (18.6 ± 2.5 minutes) compared to the conventional UVC group (33.4 ± 3.26 minutes, $p < 0.0001$). The minimum and maximum time for placement in the POCUS group ranged from 15.0 to 23.5 minutes, whereas in the conventional group, it ranged from 28.5 to 38.5 minutes. The need for post-procedural X-ray confirmation was significantly lower in the POCUS-guided UVC group (4.44%) compared to the conventional UVC group (100%, $p < 0.0001$). A majority of neonates (95.6%) in the ultrasound-guided group did not require an additional X-ray, as the catheter position was confirmed in real-time using POCUS. In contrast, all neonates in the conventional group required at least one confirmatory X-ray to verify catheter placement.*

Conclusion: *Overall, POCUS-guided UVC placement demonstrated significant advantages over the conventional method by improving procedural efficiency, reducing catheter malposition and migration, lowering complication rates, and minimizing neonatal exposure to radiation.*

Keywords: *Neonatal Intensive Care Units (NICUs), Umbilical Vein Catheterization (UVC), Point-of-Care Ultrasound (POCUS), X-rays, Conventional UVC*

INTRODUCTION

Among the most essential procedures in Neonatal Intensive Care Units (NICUs) is Umbilical Vein Catheterization (UVC), which provides a reliable route for administering life- saving treatments [1]. The conventional UVC method, while highly useful, has limitations. Incorrect catheter placement is a common challenge, potentially leading to ineffective treatment or even harm to the neonate [2]. Complications such as Catheter-Related Bloodstream Infections (CRBSI), thrombosis, perforation, and arrhythmia are frequently observed [3].

Point-of-Care Ultrasound (POCUS) is a transformative imaging modality that has redefined procedural accuracy and safety in neonatal care. POCUS involves the use of portable ultrasound devices at the bedside, enabling real-time imaging during clinical interventions [4]. Historically, reliance on anatomical landmarks and confirmatory imaging such as X-rays led to a higher incidence of procedural errors and associated complications [5]. The integration of POCUS into UVC offers distinct advantages that address the limitations of traditional methods [6]. One of the most significant benefits is the real-time visualization of umbilical vessels during the procedure [7]. This capability allows clinicians to accurately identify the umbilical vein and monitor the progress of the catheter in real time, significantly reducing the likelihood of malposition [8].

Despite the growing body of evidence supporting the benefits of POCUS, its use in UVC is not yet standardized, and its full potential remains underexplored [9]. Existing literature often focuses on isolated outcomes, such as procedural time or radiation exposure, without providing a comprehensive evaluation of its impact on success rates and complication reduction [10]. This gap underscores the need for focused studies that assess the effectiveness of POCUS-guided UVC in improving procedural outcomes and neonatal safety [11]. This study is designed to address these gaps by systematically evaluating the impact of POCUS on UVC in neonates. By comparing POCUS-guided UVC with the traditional approach, the research aims to provide robust evidence on its efficacy in enhancing procedural success and reducing complications.

Aim

To evaluate the effectiveness of Point-of-Care Ultrasound (POCUS) in guiding umbilical vein catheterization (UVC) by assessing its impact on reducing complications and improving procedural success rates in neonates.

MATERIALS AND METHODS

A single center, hospital-based comparative, prospective observational study was conducted in the Level IIIA NICU accredited by the National Neonatology Forum (NNF) at Shri Shishu Bhawan Super Speciality Hospital for Children and Newborn, Bilaspur, Chhattisgarh. Ethical clearance for this study was obtained following a thorough review of the research protocol, data collection forms, and informed consent forms by the Institute's Ethics Committee. The total duration of the present study was 12 months, spanning from January 2024 to December 2024.

The participants for the present study were neonates, both preterm and term, admitted to the NICU and requiring UVC for intravenous therapies. Eligible participants were those meeting the inclusion criteria, and their guardians provided written informed consent.

Inclusion and Exclusion Criteria:

Neonates with a birth weight of ≤1.5 kg requiring long-term intravenous fluids or nutrition, and critically ill neonates requiring early fluid resuscitation, vasoactive drugs, or other intravenous interventions were included in the study. On the other hand, neonates requiring resuscitation in the delivery room with medications, neonates with omphalitis, peritonitis, or omphalocele, necrotizing enterocolitis (NEC) or gross congenital anomalies, and abnormal development of the umbilical cord, such as a single umbilical artery were excluded from the study.

Sample size:

All eligible participants admitted to the NICU during the recruitment period and meeting the inclusion criteria were considered for enrollment. Written informed consent was obtained from the guardians. Following this approach, a total of **180 participants** were enrolled in the present study.

Study groups:

- **POCUS-Guided UVC Group:** 90 neonates in this group underwent UVC under real-time guidance using POCUS.
- **Conventional UVC Group:** 90 neonates in this group underwent UVC using the traditional anatomical landmark-based approach without ultrasound guidance.

Data recording and follow-up:

During the procedure, key data points were recorded on the structured proforma, including time required for catheter placement (measured in minutes), immediate success or failure of the procedure, and observations regarding complications during catheter insertion.

Follow-up evaluations were conducted on days 1, 3, 5, and 7 post-catheterizations. The position of the catheter tip was assessed using POCUS in the POCUS-guided group and additional X-rays if required in the conventional group. Neonatal outcomes and any adverse events were recorded on the data collection proforma.

Statistical analysis:

Chi-square or Fisher's exact test was used to compare categorical variables between the POCUS-guided and conventional UVC groups. Independent sample t-tests or Mann-Whitney U-tests were used to compare continuous variables between groups.

RESULTS

The majority of neonates in both groups were admitted within the first 24 hours of life, with 74.44% in the POCUS-guided group and 67.78% in the conventional UVC group. A smaller proportion of neonates were admitted between 25 to 48 hours (12.22% vs 21.11%), 49 to 72 hours (10.00% vs 8.89%), and beyond 72 hours (3.33% vs 2.22%) in the respective groups.

In the POCUS-guided group, 60.00% of the neonates were male and 40.00% were female, whereas in the conventional UVC group, a higher proportion of neonates were male (74.44%) compared to females (25.56%). In addition to this, vaginal delivery was more common in both groups, with 70.00% of neonates in the POCUS-guided group and 63.30% in the conventional UVC group being born through normal vaginal delivery (NVD). Conversely, caesarean section (LSCS) was performed in 30.00% of cases in the POCUS- guided group and 36.70% in the conventional UVC group. Moreover, the majority of neonates requiring UVC placement were born preterm, with a small proportion reaching term gestation. Additionally, most neonates requiring UVC placement were of low birth weight, with a higher mean birth weight observed in the POCUS-guided group.

Table 1: Indication for UVC

	POCUS Guided (n= 90)		Conventional UVC (n=90)	
	n	**%**	**n**	**%**
Respiratory failure	13	14.44	17	18.89
Nutrition	14	15.56	12	13.33
Neonatal Sepsis	7	7.78	9	10.00
Surgical	10	11.11	8	8.89
Perinatal Asphyxia	19	21.1	16	17.8
Prolong IV access	10	11.11	8	8.89
Exchange Transfusion	2	2.22	10	11.11
Shock	15	16.7	18	20.2

Table 1 highlights the indications for UVC in both study groups. The most common indication was perinatal asphyxia, accounting for 21.1% of cases in the POCUS-guided group and 17.8% in the conventional UVC group. Other major indications included respiratory failure (14.44% vs 18.89%), shock (16.7% vs 20.2%), and prolonged intravenous access (11.11% vs 8.89%). Neonatal sepsis was an indication in 7.78% of neonates in the POCUS-guided group and 10.00% in the conventional UVC group. Exchange transfusion was notably higher in the conventional UVC group (11.11%) compared to the POCUS-guided group (2.22%). These results suggest that UVC placement was required primarily for critical conditions such as perinatal asphyxia, respiratory failure, and circulatory support.

Table 2: Success in First Attempt

	POCUS Guided (n= 90)		Conventional UVC (n=90)	
	n	**%**	**n**	**%**
No	2	2.22	1	1.11
Yes	88	97.78	89	98.89
	P-value = 0.560			

According to analysis of table 2 the success rate of UVC placement on the first attempt. The majority of catheterizations were successful on the first attempt in both groups, with a success rate of 97.78% in the POCUS-guided group and 98.89% in the conventional UVC group. The failure rate was minimal, with only 2.22% of neonates in the POCUS group and 1.11% in the conventional group requiring a second attempt. The p-value of 0.560 indicates that there was no statistically significant difference between the two groups in terms of first-attempt success. This suggests that both techniques demonstrated a high rate of initial success in UVC placement.

Table 3: Distribution of Participants based on Time Required for Catheter Placement

	POCUS Guided (n= 90)		Conventional UVC (n=90)	
Mean, SD	18.6	2.5	33.4	3.26
Mini - Maxi	15.0	23.5	28.5	38.5
	P-value < 0.0001			

Table 3 highlights the time required for catheter placement in both study groups. The mean time taken for UVC placement was significantly lower in the POCUS-guided group (18.6 ± 2.5 minutes) compared to the conventional UVC group (33.4 ± 3.26 minutes). The p-value (<0.0001) indicates a statistically significant difference, suggesting that the POCUS-guided technique significantly reduced the time required for catheter placement compared to the conventional method.

Table 4: Distribution of Participants based on Location of Tip of Catheter

	POCUS Guided (n= 90)		Conventional UVC (n=90)	
	n	**%**	**n**	**%**
IVC- RA Junction	48	53.33	41	45.56
Ductous Venous	42	46.67	34	37.78
Hepatic Vein	0	0.00	8	8.89
Intra-Cardiac	0	0.00	5	5.56
Pulmonary Artery	0	0.00	2	2.22
	P-value = 0.003			

Table 4 depicts the distribution of participants based on the final location of the catheter tip. In the POCUS-guided group, the majority of catheters were successfully placed at the inferior vena cava-right atrium (IVC-RA) junction (53.33%), followed by the ductus venosus (46.67%). In contrast, in the conventional UVC group, 45.56% of catheters were positioned at the IVC-RA junction, and 37.78% were in the ductus venosus. Notably, mal-positioning of the catheter tip was observed in the conventional UVC group, with placements in the hepatic vein (8.89%), intracardiac region (5.56%), and pulmonary artery (2.22%), whereas no such misplacements were observed in the POCUS-guided group. The p- value (0.003) indicates a statistically significant difference, reinforcing the effectiveness of POCUS in ensuring correct catheter placement and minimizing mal-positioning.

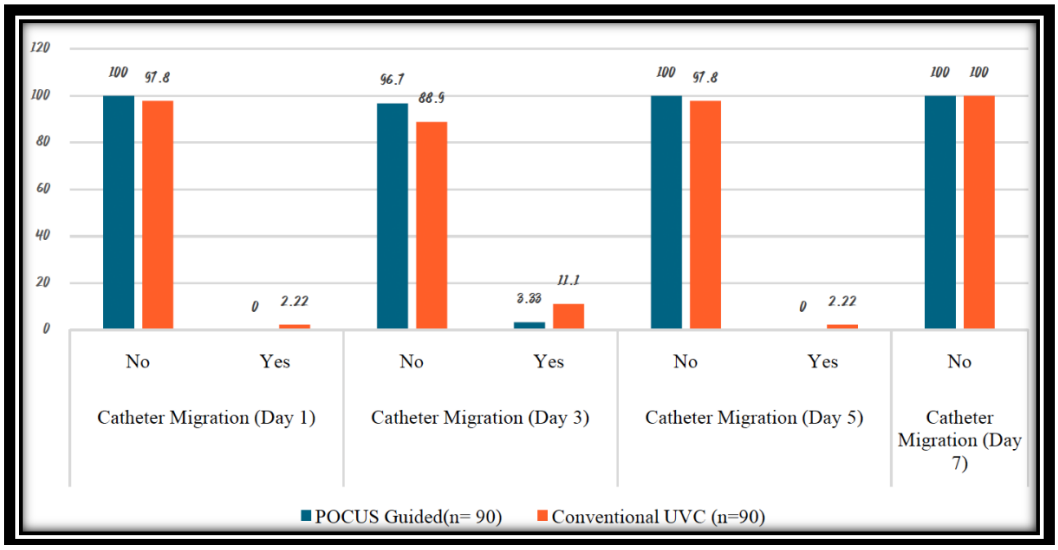

Figure 1: Distribution of participants based on day wise Cather migration

From the above analysis, it has been considered that POCUS-guided UVC placement significantly reduces catheter migration, particularly in the first few days of post-procedure.

Table 5: Cumulative / Total Migration

	POCUS Guided (n= 90)		**Conventional UVC (n=90)**	
	n	**%**	**n**	**%**
No	87	96.67	77	85.56
Yes	3	3.33	13	14.44
	P-value = 0.009			

As per the analysis above, the cumulative catheter migration throughout the study period. A total of 3.33% of neonates in the POCUS-guided group experienced migration compared to 14.44% in the conventional UVC group. The p-value (0.009) indicates a statistically significant difference, confirming that the use of POCUS for UVC placement results in significantly lower catheter migration rates compared to the conventional technique.

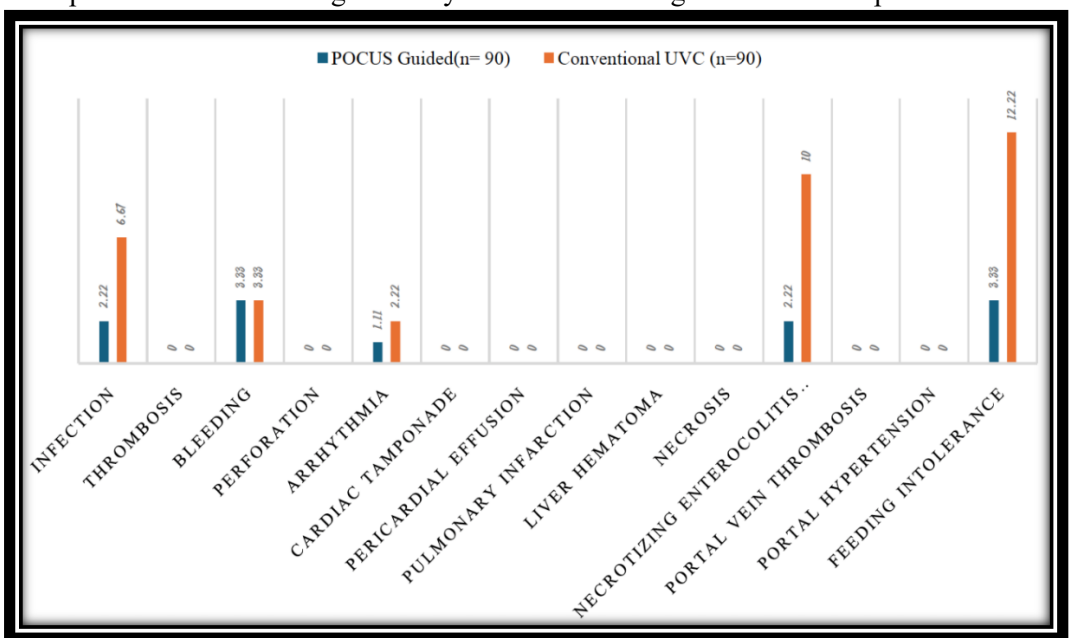

Figure 2: Complications

As per the analysis above, POCUS-guided UVC placement is associated with lower rates of certain complications, particularly NEC and feeding intolerance.

Apart from this, the number of X-rays required for confirming catheter placement in both study groups. In the POCUS-guided group, 95.6% of neonates did not require any X-rays, while only 4.44% needed at least one X-ray for confirmation. In contrast, in the conventional UVC group, 100% of neonates required X-ray confirmation. The p-value (<0.0001) indicates a statistically significant difference, demonstrating that POCUS-guided UVC placement significantly reduces the need for X-ray exposure, thereby minimizing radiation-related risks in neonates.

DISCUSSION

The present study was conducted in the Level IIIA NICU at Shri Shishu Bhawan Super Speciality Hospital for Children and Newborn, Bilaspur, Chhattisgarh, a tertiary care referral center for critically ill neonates, to evaluate the effectiveness of POCUS in guiding UVC by assessing its impact on procedural success rates, complication reduction, and time efficiency. The study included a total of 180 neonates, who were divided into two groups: 90 neonates underwent POCUS-guided UVC, while 90 neonates underwent conventional UVC using anatomical landmarks.

In the present study, the mean time required for catheter placement was significantly lower in the POCUS-guided UVC group (18.6 ± 2.5 minutes) compared to the conventional UVC group (33.4 ± 3.26 minutes, $p < 0.0001$). The minimum and maximum time for placement in the POCUS group ranged from 15.0 to 23.5 minutes, whereas in the conventional group, it ranged from 28.5 to 38.5 minutes. These findings suggest that ultrasound guidance significantly reduces the procedural duration, which has critical implications for neonatal care by minimizing procedural stress and potential complications associated with prolonged catheterization attempts. Similarly, Anne et al. (2025) [12], in a systematic review of six studies, reported a significant reduction in procedure duration with real-time ultrasound guidance (mean difference -6.1 minutes, 95% CI -8.4 to -3.8 minutes, ($p < 0.05$) in randomized controlled trials (RCTs), reinforcing the time efficiency of ultrasound over conventional techniques.

In the present study, the need for post-procedural X-ray confirmation was significantly lower in the POCUS-guided UVC group (4.44%) compared to the conventional UVC group (100%, $p < 0.0001$). A majority of neonates (95.6%) in the ultrasound-guided group did not require an additional X-ray, as the catheter position was confirmed in real-time using POCUS. In contrast, all neonates in the conventional group required at least one confirmatory X-ray to verify catheter placement. Several studies have supported the role of POCUS in reducing reliance on X-rays for UVC confirmation. Michel et al. (2012) [13] found that ultrasound had a significantly higher accuracy in determining UVC tip position compared to X-ray. The study reported that ultrasound eliminated the need for repeated X-rays in 94% of cases, thereby reducing radiation exposure and procedural time.

In the present study, total catheter migration was significantly lower in the POCUS- guided UVC group (3.33%) compared to the conventional UVC group (14.44%), with a statistically significant difference ($p = 0.009$). The majority of catheters in the POCUS group remained correctly positioned (96.67%), whereas 13 catheters (14.44%) in the conventional group experienced migration. These findings indicate that real-time ultrasound guidance plays a crucial role in minimizing catheter displacement, thereby reducing the risk of complications associated with mal-positioned catheters. Further supporting evidence comes from Gupta et al. (2019) [14], who found that real-time ultrasound guidance reduced the risk of catheter migration to 3.9% compared to 16.7% with the conventional method ($p < 0.001$). Their study emphasized that post-insertion migration is often caused by excessive initial insertion, which can be mitigated by ultrasound-assisted adjustments.

In the present study, the overall complication rates were lower in the POCUS-guided UVC group compared to the conventional UVC group, with notable differences in infection, necrotizing enterocolitis (NEC), and feeding intolerance. The incidence of infection was lower in the POCUS group (2.22%) compared to the conventional group (6.67%), although the difference was not statistically significant ($p = 0.148$). NEC was significantly lower in the POCUS group (2.22%) compared to the conventional group (10.00%, $p = 0.029$), while feeding intolerance was also significantly reduced (3.33% vs. 12.22%, $p = 0.026$). Other complications, such as bleeding (3.33% in both groups), arrhythmia (1.11% vs. 2.22%), and thrombosis (0% in both groups), did not show statistically

significant differences. Vieira et al. (2021) [15] also observed that the incidence of infection was lower in the ultrasound group (3.2%) compared to the conventional group (7.5%, p = 0.041). They also found that feeding intolerance was reduced in neonates with correctly positioned catheters, which is consistent with the present study's results.

CONCLUSION

The majority of neonates requiring UVC were admitted within the first 24 hours of life, highlighting the critical need for early vascular access in neonatal intensive care. The POCUS-guided technique was associated with a significantly higher mean birth weight compared to the conventional UVC group, though both groups were predominantly composed of low-birth-weight neonates. The time required for catheter placement was significantly shorter in the POCUS-guided group, confirming that real-time ultrasound guidance improves procedural efficiency. Overall, POCUS-guided UVC placement demonstrated significant advantages over the conventional method by improving procedural efficiency, reducing catheter malposition and migration, lowering complication rates, and minimizing neonatal exposure to radiation.

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