JPPT | Single Center Retrospective Study

Safety of Short-Term Parenteral Nutrition Administration Through Umbilical Artery Catheters in Neonates While in the Neonatal Intensive Care Unit

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OBJECTIVE The use of umbilical artery catheters (UACs) for parenteral nutrition (PN) administration is controversial, and limited data exist on the safety of administration through this route. The objective of this research is to evaluate neonates who received PN through a UAC and assess catheter-related complications and PN composition.

METHODS This retrospective study evaluated all neonates who received PN through their UAC while admitted in the neonatal intensive care unit between January 2019 and December 2022. Neonates were evaluated for development of catheter-related complications such as infiltration, extravasation, thrombus formation, infection, or hypertension.

RESULTS The administration of PN through UAC was identified in 31 neonates. Among the 31 neonates, 17 (55%) were classified as preterm, and 15 (48%) were classified as low birth weight. No patient experienced a UAC-related complication. Death occurred among 7 (23%) neonates. Two deaths occurred while the neonates were receiving PN via the UAC, but neither death was attributed to UAC complications. In 19 (61%) of the 31 neonates, osmolarity of PN exceeded 900 mOsm/L.

CONCLUSIONS Results of this study suggest that UACs may serve as a safe route for PN administration in neonates. The absence of catheter-related complications and the absence of adverse events support the safety of this approach. Further research with a larger sample size and rigorous study design is warranted to validate these findings and establish guidelines for the use of UACs in PN administration.

ABBREVIATIONS EMR, electronic medical record; NEC, necrotizing enterocolitis; NICU, neonatal intensive care unit; PN, parenteral nutrition; UAC, umbilical artery catheter; UVC, umbilical venous catheter

KEYWORDS neonatal intensive care unit; neonates; parenteral nutrition; safety; umbilical artery catheter

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Introduction

Parenteral nutrition (PN) administration in preterm neonates can be essential as a sole source of nutrition or as a supplement to enteral feedings to meet the nutrient needs to achieve appropriate physiologic growth rates.[1] Growth failure remains an important issue in preterm neonates and is linked to impaired neurocognitive outcomes.[2,3] Parenteral nutrition administration is usually accomplished via peripheral or central veins.

Umbilical arterial catheters (UACs) have been widely used in neonatal intensive care units (NICUs) for various purposes, including blood gas sampling, blood pressure monitoring, cardiac catheterizations, PN, and exchange transfusions.[4,5] These catheters offer a convenient means of obtaining vascular access, especially in neonates where venous access can be difficult owing to the fragility of veins.[6]

Controversy surrounds the administration of medications, including PN through a UAC, owing to the potential for complications. These complications include embolism, vasospasm, thrombosis, blood vessel perforation, hemorrhage, hypertension, and infection.[5,7,8] Despite the controversy, a survey of 130 NICUs found that 40% still administered PN via UACs.[9]

Given the limited available literature and the conflicting findings regarding the safety of PN administration through UACs, there is a need for further investigation to assess the potential risks and benefits associated with this route of administration. This study aims to determine the safety of administering PN through UACs, focusing on catheter-related complications and the characteristics of PN.

Materials and Methods

This was a single center retrospective observational study to assess the safety of PN administration via UACs

in neonates during their admission to the Le Bonheur Children's Hospital NICU between January 2019 and December 2022. All neonates who received PN were screened to determine if they had a UAC present during the time they received PN. The electronic medical record (EMR) of those infants found to have a UAC while receiving PN were reviewed to determine if PN was administered via the UAC.

The study population included all neonates who received PN through UACs during their stay in the NICU. The NICU standard for placement of UACs is to use a high-lying position with the catheter tip between vertebrae T6 and T10 verified by x-ray. Data were collected from the EMR of the neonates. The following demographic variables were extracted for analysis: age, sex, gestational age, birth weight, and underlying medical conditions. Parenteral nutrition characteristics (osmolarity, nutrient composition, and duration of PN administration through the UAC) and the occurrence and timing of death during the NICU admission were noted. The primary outcome parameter was a UAC-related complication that included infiltration, extravasation, thrombus formation, infection or sepsis, hypertension (requiring the initiation of an antihypertensive), and necrotizing enterocolitis (NEC). The patient's EMR including progress notes, radiology reports, medication administration record, and laboratory reports were reviewed during the period each patient received PN via a UAC to identify if a UAC-related complication occurred.

Descriptive statistics using Excel 16.80 (Microsoft Corporation) were used to summarize all extracted data and included median with range for continuous variables, and frequencies with percentages for categorical variables.

Results

A total of 31 neonates received PN through their UAC. An additional 6 patients were receiving PN through a UAC upon transfer from an outside hospital, but PN was discontinued on admission to our NICU and these patients were excluded. Baseline patient characteristics are presented in Table 1. Approximately half (17/31) of the neonates were preterm, with 5 (16%) being extremely preterm. Additionally, half (15/31) of the neonates were classified as low birth weight (<2500 g), with 5 (16%) being very low birth weight (<1500 g). The median duration of UAC placement was 6 days, and the median duration of PN infusion through the UAC was 2 days. No patient had a documented UAC-related complication (infiltration/extravasation, infection, sepsis, or hypertension necessitating the initiation of antihypertensive medication; or the development of NEC). UACs were electively removed in 27 neonates, 2 UACs were removed when they became unsutured, and 2 deaths occurred due to respiratory failure at the time PN was infusing via the UAC; however, neither death was attributed to UAC-related complications. There were 5 additional deaths, 4 respiratory related and 1 cardiac related, that occurred 11 to 90 days after the UACs were removed.

Parenteral nutrition characteristics are summarized in Table 2. The PN osmolality exceeded 900 mOsm/L in 19 (61.3%) infants, with 10 (32%) patients exceeding 1000 mOsm/L. Additionally, 5 (16%) patients had a PN dextrose concentration that exceeded 12.5%, and 24 (77%) had a PN calcium concentration that exceeded 20 mEq/L (our institution's maximum concentration for peripheral administration). Most (28/31) patients received lipid injection emulsion via Y-site infusion with PN.

Discussion

The safety of PN administration through UACs in neonates has been controversial, with some institutions restricting UACs to only blood gas monitoring and others allowing the administration of medications, fluids, blood products, and PN. This study aimed to evaluate the safety of PN via UACs by examining the occurrence of catheter-related complications and the characteristics of PN administration.

One of the key findings of this study was the absence of UAC-related complications among the 31 neonates who received PN through UACs. Complications such as infiltration, extravasation, thrombus formation, infection, hypertension, and NEC were not observed while patients were receiving PN via a UAC. This contrasts with prior studies observing catheter-related complications.

Table 1. Patient Characteristics (N = 31)

Males, n* (%)	13 (42)
Gestational age, median (range), wk	36 (23–40)
≥37, n (%)	14 (45)
≥28 to <37, n (%)	12 (39)
<28, n (%)	5 (16)
Postnatal age PN* first administered via UAC*, median (range), day	2 (1–14)
Birth weight, median (range), g	2550 (480–4400)
≥2500, n (%)	16 (52)
≥1500 to <2500, n (%)	10 (32)
<1500, n (%)	5 (16)
Duration of UAC line, median (range), day	6 (3–26)
Duration of PN through UAC line, median (range), day	2 (1–19)
Death, n (%)	7 (22)
Occurred during PN administration via UAC†	2 (6)
Occurred after PN administration via UAC stopped	5 (16)

PN, parenteral nutrition; UAC, umbilical artery catheter

* n, number.

† Deaths were not related to UAC complications.

A comparative study between UACs and umbilical venous catheters (UVCs) found transient hypertension in 2 (4%) of 48 neonates in the UAC group versus 1 (3.8%) of 26 in the UVC group.[10] Additionally, 1 occurrence of aortic thrombosis was observed in the UAC group, while none occurred in the UVC group. Sepsis was found in 5 (10.4%) of 48 in the UAC group compared with 4 (19%) of 26 in the UVC group. Another study, by Hall and Rhodes,[11] reviewed PN administration via UACs in 80 neonates reporting catheter complications in 20 (25%) of the 80 patients.[11] These complications included 13 positive blood cultures, 3 clotted catheters, 3 cyanotic legs, and 1 thrombotic event. Moreover, death occurred among 15 patients, with 5 potentially being catheter-related deaths. We observed death in 2 neonates who were receiving PN via a UAC, but there were no UAC-related complications identified. An additional 5 patients died during their hospitalization after their UAC had been electively discontinued. The high mortality rate of 23% is likely due to the critical condition of these neonates and the temporary lack of an alternative catheter site for the administration of PN, necessitating the short-term need to administer PN via their UAC.

The lack of UAC-related complications in our study can be attributed to several factors. First, the duration of UAC placement and PN infusion was relatively short in this study, with median durations of 6 days and 2 days, respectively. Median duration of the UAC in this study aligns with the recommendations for optimal UAC use of around 5 days.[12] Shorter durations of UAC use may reduce the risk of complications, as prolonged catheter dwell time has been associated with an increased likelihood of complications such as infection and thrombus formation. The use of the UAC for administration of PN was often a bridge until the placement of an alternative venous catheter for PN administration. Allowing for the use of UACs may potentially prevent deficiencies in providing adequate nutrients for growth. Additionally, vigilant monitoring and proper catheter care protocols may have contributed to the absence of complications.

Table 2. PN Characteristics (N = 31)

Max infusion rate, median (range), mL/kg/hr	4.1 (1.7–5.7)
Max osmolarity, median (range), mOsm/L	939 (744–1452)
Osmolarity <900 mOsm/L, n (%)	12 (39)
Osmolarity 900–1000 mOsm/L, n (%)	9 (29)
Osmolarity >1000 mOsm/L, n (%)	10 (32)
Max dextrose infused, median (range), %	10 (7.5–20)
Dextrose >12.5%, n (%)	5 (15)
Max calcium infused, median (range), mEq/L	25 (0–30)
Calcium >20 mEq/L, n (%)*	24 (77)
Max potassium infused, median (range), mEq/L	17 (0–33)
Lipid injectable emulsion, n (%)	28 (89)

PN, parenteral nutrition

* 20-mEq/L calcium is the institutional maximum concentration for peripheral administration.

Previous studies did not expound on the contents of the PN or the duration of use. A notable finding of our study was the variation in the electrolyte composition and the resulting osmolarity of the PN solutions administered via UACs. Potassium concentration ranged from 0 to 33 mEq/L, which is less than 40 mEq/L, the maximum recommended for peripheral intravenous infusion.[13] A total of 24 of 31 patients had calcium gluconate concentrations greater than 20 mEq/L, which is our institutional maximum concentration for peripheral intravenous infusion. Slightly more than half of the PN solutions exceeded an osmolarity of 900 mOsm/L, with a significant proportion exceeding 1000 mOsm/L. Higher osmolarities in PN solutions may increase the risk of complications such as thrombus formation and vessel irritation. Therefore, it is crucial to carefully monitor and adjust the osmolarity of PN solutions to minimize the potential adverse effects. While this study did not review the functionality of the umbilical arterial line as a peripheral versus central line for nutritional support, the American Society for Parenteral and Enteral Nutrition recommends maintaining an osmolarity below 900 mOsm/L in peripheral lines.[14] Most patients exceeded this recommendation, and more research is needed to evaluate the use of UACs with central PN limits to maximize nutritional and electrolyte support.

Limitations of this study include the retrospective nature of the data collection and the fact that the study period ended when the UAC was removed. Catheter-related complications such as infection, hypertension, or thrombus formation post removal could have occurred after the catheter was removed, which was after the study period. The patient sample was relatively small, with no comparison group, and the duration for PN administration via the UAC was only a median of 2 days.

Further research is warranted to corroborate these findings and establish evidence-based guidelines for the safe administration of PN via UACs in neonates. Prospective studies with larger sample sizes, multicenter collaborations, and standardized protocols are needed to provide more robust evidence on the safety and optimal management of PN via UACs.

Conclusions

This study provides evidence suggesting PN administration through UACs may be a safe practice in the NICU at least as a short-term bridge to the placement

of alternative vascular access. Future research should focus on addressing the limitations of this study and establishing comprehensive guidelines for the safe and effective use of UACs for PN administration in neonatal care.

Article Information

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References

1. Wiechers C, Bernhard W, Goelz R, et al. Optimizing early neonatal nutrition and dietary pattern in premature infants. *Int J Environ Res Public Health*. 2021;18(14):7544.
2. Franz AR, Pohlandt F, Bode H, et al. Intrauterine, early neonatal, and post discharge growth and neurodevelopmental outcome at 5.4 years in extremely preterm infants after intensive neonatal nutritional support. *Pediatrics*. 2009;123(1):e101–e109.
3. Ehrenkranz RA, Dusick AM, Vohr BR, et al. Growth in the neonatal intensive care unit influences neurodevelopmental and growth outcomes of extremely low birth weight infants. *Pediatrics*. 2006;117(4):1253–1261.
4. Fletcher MA, Brown DR, Landers S, Seguin J. Umbilical arterial catheter use: report of an audit conducted by the Study Group for Complications of Perinatal Care. *Am J Perinatol*. 1994;11(2):94–99.
5. Green C, Yohannan MD. Umbilical arterial and venous catheters: placement, use, and complications. *Neonatal Netw.* 1998;17(6):23–28.
6. Stovroff M, Teague WG. Intravenous access in infants and children. *Pediatr Clin North Am*. 1998;45(6):1373–viii.
7. Butt WW, Gow R, Whyte H, et al. Complications resulting from use of arterial catheters: retrograde flow and rapid elevation in blood pressure. *Pediatrics*. 1985;76(2):250–254.
8. Elboraee MS, Toye J, Ye XY, et al. Association between umbilical catheters and neonatal outcome in extremely preterm infants. *Am J Perinatol*. 2018;35(3):233–241.
9. Smith L, Dills R. Survey of medication administration through umbilical arterial and venous catheters. *Am J Health Syst Pharm.* 2003;60(15):1569–1572.
10. Kanarek KS, Kuznicki MB, Blair RC. Infusion of total parenteral nutrition via the umbilical artery. *JPEN J Parenter Enteral Nutr.* 1991;15(1):71–74.
11. Hall RT, Rhodes PG. Total parenteral alimentation via indwelling umbilical catheters in the newborn period. *Arch Dis Child.* 1976;51(12):929–934.
12. O'Grady NP, Alexander M, Burns LA, et al. Summary of recommendations: Guidelines for the Prevention of Intravascular Catheter-related Infections. *Clin Infect Dis*. 2011;52(9):1087–1099.
13. Potassium chloride injection [package insert]. Accessed October 2023. https://dailymed.nlm.nih.gov/dailymed/fda/fdaDrugXsl.cfm?setid=951ffdc3-d54f-d5e1-e053-2a95a90a79e6&type=display#:~:text=If%20the%20serum%20potassium%20level,should%20not%20exceed%20200%20mEq
14. Boullata JI, Gilbert K, Sacks G, et al. A.S.P.E.N. clinical guidelines: parenteral nutrition ordering, order review, compounding, labeling, and dispensing. *JPEN J Parenter Enteral Nutr*. 2014;38(3):334–377.