ORIGINAL RESEARCH ARTICLE

Effectiveness of full-cycle indwelling needle management in neonates and its protective role against post-bath puncture site infections and bleeding

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Abstract

Intravenous access is a critical component of clinical care for neonates. Given neonates' underdeveloped vascular systems, fragile skin barrier, and immature immune responses, they experience substantially higher rates of catheter-related complications (including infections and bleeding) compared to adult populations. This research introduces an innovative Full-Cycle Indwelling Needle Management (FCINM), establishing a tripartite framework of "Evaluation-Implementation-Surveillance". By combining advanced dressing techniques and proactive maintenance protocols, this approach significantly enhances first-attempt success rates (92.0% *vs.* 74.0%, p=0.017) while reducing catheterization time. Post-implementation results showed reductions in complication rates, along with improvements in care adherence. Compared with the standard care group, the observation group showed no significant difference in puncture site infection rates, the observation group demonstrated significantly lower infection rates through antimicrobial-impregnated dressings and proactive maintenance approaches. In conclusion, FCINM enhances the accuracy and safety of neonatal intravenous therapy by integrating technological advancements and procedural refinements. *(Afr J Reprod Health 2025; 29 [12]: 115-121).*

Keywords: Intravenous catheter; neonates; infection; bleeding; full-cycle management

Résumé

L'accès intraveineux est un élément essentiel des soins cliniques pour les nouveau-nés. Compte tenu du sous-développement de leur système vasculaire, de la fragilité de leur barrière cutanée et de l'immaturité de leur système immunitaire, ces derniers présentent des taux de complications liées au cathéter (notamment infections et saignements) nettement plus élevés que les adultes. Cette recherche présente une approche innovante de gestion des aiguilles à demeure à cycle complet (FCINM), établissant un cadre tripartite « Évaluation-Mise en œuvre-Surveillance ». En combinant des techniques de pansement avancées et des protocoles de maintenance proactive, cette approche améliore significativement les taux de réussite à la première tentative (92,0 % contre 74,0 %, p = 0,017) tout en réduisant la durée du cathétérisme. Les résultats post-mise en œuvre ont montré une réduction des taux de complications et une amélioration de l'observance des soins. Comparativement au groupe de soins standard, le groupe d'observation n'a montré aucune différence significative concernant les taux d'infection au site de ponction ; le groupe d'observation a démontré des taux d'infection significativement plus faibles grâce aux pansements imprégnés d'antimicrobiens et aux approches de maintenance proactive. En conclusion, la FCINM améliore la précision et la sécurité du traitement intraveineux néonatal grâce à l'intégration des avancées technologiques et des améliorations procédurales. *(Afr J Reprod Health 2025; 29 [12]: 115-121).*

Mots-clés: Cathéter intraveineux ; nouveau-nés ; infection ; saignement ; prise en charge complète du cycle

Introduction

Intravenous therapy is a vital aspect of nursing care for neonates. However, the application of intravenous indwelling needles in this population presents challenges, including complications like infections and bleeding. These issues arise due to the delicate nature of neonatal blood vessels, underdeveloped skin defenses, and an immature immune system.[1] These vulnerabilities are further compounded by the frequent exposure of puncture sites to moisture during bathing, creating a synergistic risk environment for infections. Studies indicate that phlebitis occurs in 5% to 15% of cases, with infections often linked to inadequate needle maintenance.[2] Bathing, a routine part of neonates care, introduces additional risks as moisture exposure at the needle site may worsen these

complications.[3] While sterile dressings are commonly used to protect puncture sites and minimize infection risk, the absence of standardized protocols for bathing procedures continues to pose challenges, increasing the likelihood of infections and bleeding.[4] Ensuring the secure fixation of indwelling needles while maintaining hygiene during bathing remains a pressing concern in neonatal nursing practice.

Currently, numerous clinical studies have been conducted on the maintenance of intravenous indwelling catheters. For instance, the European Association for Paediatric Nursing (EANC) advocates a triple fixation approach using transparent dressings with elastic bandages, demonstrating effectiveness in reducing bleeding complications.[5] Chinese domestic research has demonstrated that utilizing hydrocolloid dressings in conjunction with the elevated platform technique significantly prolongs catheter retention duration.[6] However, existing interventions primarily concentrate on enhancing puncture methodologies, while research on targeted preventive measures for specific scenarios, such as post-bathing care, remains insufficient. This gap is particularly evident in vulnerable populations, including premature infants, neonatal pneumonia, and neonatal sepsis, where compromised skin barrier function complicates nursing procedures. Hence, there is a pressing need to develop a comprehensive risk management framework to address these challenges. This study introduces an innovative approach called "Full-Cycle Indwelling Needle Management (FCINM)," establishing a tripartite framework integrating "evaluation, implementation, and surveillance." Notably, it expands indwelling needle risk management to include bathing procedures for the first time. Additionally, the research develops a novel combination therapy using medical-grade silicone foam dressings with antimicrobial coatings, overcoming the restricted protective capacity of conventional dressings. The findings demonstrate potential benefits in minimizing neonatal dermal trauma and healthcare-associated infections while advancing infusion care toward more targeted and context-specific practices. This advancement is poised to enhance precision and context-specific practices in intravenous therapy nursing, ultimately improving care standards in both neonatal intensive care units (NICUs) wards while establishing more compassionate and secure protections for vulnerable neonates.

Methods

Research design

This study employs a prospective, double-blind, randomized controlled trial (RCT) design, adhering to the CONSORT (Consolidated Standards of Reporting Trials) guidelines to ensure methodological rigor, scientific validity, and reproducibility.

Study population

The study population comprised neonates admitted to our hospital's Neonatology Department for intravenous indwelling needle infusion therapy between May 2024 and June 2025. The sample size was calculated using specialized statistical software based on an α value of 0.05, yielding a minimum required sample size of 42 participants per group. Accounting for a potential 10% attrition rate, 100 neonates were enrolled to ensure adequate statistical power. Eligible participants were sequentially numbered according to their admission order and randomly assigned to one of two study groups using a computer-generated random number table: a conventional group (n=50) receiving standard routine nursing care for intravenous indwelling needles, and an observation group (n=50) further intervened by the FCINM.

Inclusion and exclusion criteria

Inclusion Criteria: ① Gestational age ≥28 weeks (preterm infants requiring gestational age correction to >30 weeks); ② Neonates aged ≤28 days; ③ Initial or repeated intravenous indwelling needle insertion (BD 24G/22G) for clinical indications (e.g., intravenous nutrition, antibiotics, or fluid therapy); ④ Parental informed consent and willingness to complete the study (follow-up until 72 h post-catheter removal). Exclusion Criteria: ① Severe dermatological conditions (e.g., epidermolysis bullosa, severe eczema) or skin lesions at the puncture site; ② Coagulation disorders (platelets $<50\times10^9$/L or D-dimer >2 mg/L); ③ Expected survival <72 h; ④ Parental withdrawal (defined as discontinuation of consent or failure to

comply with follow-up visits for >48 hours), non-compliance, or loss to follow-up (e.g., due to hospital transfer); ⑤ Pregnant women with comorbid pregnancy diseases.

Methods of care

The routine care used in the conventional group was performed as follows: ① Pre-puncture care: The puncture site was disinfected, and the disinfected area was ≥8cm×8cm [using 0.5% iodophor solution (w/v)]. ② Post-puncture care: The site was secured with a 3M transparent dressing (10 cm × 12 cm). The heparin cap was positioned 1~2 cm above the puncture point, and moderate compression was applied using an elastic bandage (ensuring it did not impede blood circulation). ③ Daily maintenance: Dressings were changed every 72 h (or immediately if bleeding or oozing occurred). Strict aseptic techniques were followed during dressing changes. ④ Bathing care: Before bathing, the puncture site was wrapped with medical-grade polyethylene (PE) film to prevent direct water exposure. After bathing, the dressing integrity was checked immediately, and a new dressing was applied once the area was dry.

The observation group implemented the indwelling needle management method based on the above-mentioned standard care: (1) Full-cycle Assessment (spanning the entire indwelling period). ① Pre-insertion Assessment: Utilizing the Neonatal Venous Risk Assessment Scale, assessments were conducted on skin barrier function (e.g., elasticity, presence of lesions), vascular characteristics (diameter, turgor), and infection susceptibility (evaluated via body temperature, leukocyte count, and C-reactive protein levels). ② Intra-insertion Evaluation: The puncture site was recorded (classified as scalp/upper limb/lower limb), along with the catheter model and length, and the fixation angle (15°~30° to the skin). ③ Post-Insertion Assessment: Dynamic monitoring of the puncture site was performed, including daily inspection for localized erythema, swelling extent, and amount of bleeding/exudate. Additionally, dressing integrity (assessed for moisture or detachment) and catheter exposure post-bathing (with recorded bathing duration and water contact time) were evaluated. (2) Targeted Intervention (focusing on bathing procedures and infection prevention): ① Dressing Upgrade: A dual-layer dressing system was implemented, combining medical-grade silicone foam dressings (3M Tegaderm™ foam) for pressure relief and friction reduction with an antibacterial-coated transparent film [0.5% chlorhexidine-impregnated transparent film (w/v)] to inhibit microbial growth. ② Bathing Protection: A "sandwich" fixation technique was developed—the inner layer consisted of silicone foam dressings (covering the puncture site and surrounding 2 cm of skin), the middle layer was a waterproof and breathable film (3M™ Cavilon™ No-Sting Barrier Film), and the outer layer was an elastic net sleeve (to secure the dressing and limit arm movement range). ③ Dynamic Maintenance: Dressing change intervals were tailored to risk levels (48 h for high-risk cases and 72 h for low-risk). During dressing changes, a "tension-free application method" was used (placing the dressing's center on the needle site with smooth, unbuckled edges). (3) Multi-dimensional Monitoring (tracking of infection and bleeding indicators): ① Infection Monitoring: Within 72 h after needle removal, secretions from the needle site were collected for bacterial culture within 72 hours after catheter removal (aerobic + anaerobic bacteria). Redness diameter (>2 cm was considered positive) and the nature of exudate (purulent discharge signifying infection) were recorded. ② Bleeding Monitoring: Transparent grid paper was used to measure the bleeding area (>0.5 cm^2 indicated bleeding), and the duration of bleeding (interval between needle withdrawal and complete hemostasis) was recorded. ③ Indwelling Duration: The period between catheter placement and withdrawal was recorded (in cases where the catheter was removed prematurely due to complications, the true duration was documented).

Quality control

Prior to the study, all participating nurses underwent standardized training (theoretical instruction + practical skill evaluation). Only participants achieving a minimum passing score of 90% were included, to ensure the quality of nursing services. Two researchers independently entered the data into an electronic database, and SPSS 26.0 was used for consistency testing (Kappa value>0.8). Infection indicators (bacterial culture, exudate properties) were assessed blindly by laboratory physicians and dermatologists not involved in the nursing process. Blinding was maintained for outcome assessors (laboratory physicians and dermatologists) who

were unaware of group allocation. Nursing interventions could not be blinded due to operational differences.

Outcome measures

① Puncture and catheterization conditions were recorded, including the number of puncture attempts, first-attempt success rate, catheterization duration, and incidence of skin damage. ② Safety: Intravenous indwelling needle-related adverse events during nursing were recorded, such as post-bathing puncture site infections, exudation, phlebitis, etc. The total incidence rate was calculated (if a single neonate experienced multiple adverse events, each was counted independently). ③ Compliance survey: Neonates were considered fully compliant if they cooperated with nursing care, exhibited no crying or limb movements, and remained emotionally stable. Partial compliance was defined as basic cooperation with some resistance or restlessness. Non-compliance referred to uncooperative behavior, persistent crying, excessive limb movements, or interference with treatment procedures and examinations.

Statistical methods

Statistical analyses were conducted using SPSS 26.0. Continuous variables were evaluated for normality using the Shapiro-Wilk test and are reported as mean ± standard deviation (Mean ± SD, $\bar{\chi}\pm s$) if normally distributed. Independent group comparisons were analyzed with Student's t-test, whereas within-group comparisons utilized paired t-test. Categorical variables are presented as frequencies (percentages) and were compared between groups using either chi-square tests or Fisher's exact test, as appropriate. Statistical significance was defined as a two-tailed p-value<0.05.

Ethical consideration

The study protocol received approval from Lixin County People's Hospital Institutional Review Board (No. kl2024012;2024-12), parents of all children were informed and consented to the study.

Results

Comparison of clinical baseline data

The two neonates groups exhibited comparable clinical baseline characteristics (such as age in days, gender, gestational age, etc.) (p>0.05, Table 1), indicating comparability.

Table 1: Clinical baseline data

Projects	Conventional (n=50)	Observation (n=50)	t or χ^2	p
Age in days (d)	16.90±3.63	17.06±5.80	0.165	0.869
Gender			0.360	0.548
male	26 (52.00)	23 (46.00)		
female	24 (48.00)	27 (54.00)		
Gestational age (weeks)	33.00±2.48	32.38±2.35	1.283	0.202
Birth weight (kg)	1.99±0.62	1.97±0.59	0.107	0.915
Only child			0.877	0.349
yes	36 (72.00)	40 (80.00)		
no	14 (28.00)	10 (20.00)		
Mode of delivery			1.099	0.295
natural birth	30 (60.00)	35 (70.00)		
cesarean section	20 (40.00)	15 (30.00)		

Table 2: Puncture and catheterization conditions

Projects	Conventional (n=50)	Observation (n=50)	t or χ^2	P
Skin damage	9 (18.00)	4 (8.00)	2.210	0.137
Number of punctures	1.38±0.73	1.10±0.36	2.439	0.017
Catheterization time (min)	8.74±2.21	6.12±1.47	6.983	<0.001
First-attempt success	37 (74.00)	46 (92.00)	5.741	0.017

Table 3: Adverse events

Adverse reactions	Conventional (n=50)	Observation (n=50)	χ^2	P
Bleeding	5 (10.00)	3 (6.00)		
Accidental needle removal	4 (8.00)	1 (2.00)		
Needle detachment	4 (8.00)	2 (4.00)		
Hematoma	2 (4.00)	1 (2.00)		
Phlebitis	1 (2.00)	0 (0.00)		
Incidence of adverse reactions	16 (32.00)	7 (14.00)	4.574	0.033

Note: Accidental needle removal: unintentional catheter dislodgement by external forces Needle detachment: separation of catheter hub from extension tube.

Table 4: Nursing compliance

Compliance level	Conventional (n=50)	Observation (n=50)	χ^2	P
Non-compliance	18 (36.00)	8 (16.00)		
Partial	22 (44.00)	26 (52.00)		
Fully	10 (20.00)	16 (32.00)		
Total compliance rate	32 (64.00)	42 (84.00)	5.198	0.023

Comparison of puncture and catheterization conditions

Statistical analysis showed no marked inter-group difference in the incidence of skin damage ($p>0.05$). However, the observation group required fewer puncture attempts, achieved a higher first-attempt success rate, and completed catheter placement faster than the conventional group ($p<0.05$, Table 2).

Comparison of adverse events

Neither group experienced puncture site infections, but incidents such as exudation and accidental needle dislodgement were observed. The total incidence rate in the observation group was 10%, significantly lower than that in the conventional group (14.00% *vs.* 32.00%, $p<0.05$, Table 3).

Comparison of nursing compliance

In terms of compliance, the total compliance rate in the observation group was 84.00% (42/50), significantly outperforming the 64.00% (32/50) in the conventional group ($p<0.05$, Table 4).

Discussion

The observation group exhibited a statistically higher first-attempt success rate, reduced puncture attempts, and shorter procedural duration. These results corroborate existing literature,[7,8] suggesting that comprehensive, FCINM can significantly improve puncture efficiency. Neonatal vascular access presents unique challenges due to complex vascular anatomy, where conventional techniques often depend on operator skills. The implementation of standardized evaluation using the Neonatal Venous Risk Assessment Scale—incorporating parameters like vessel diameter and turgor—has been shown to improve target selection precision.[9] Furthermore, the innovative "sandwich" stabilization technique, employing a triple-layer configuration of silicone foam dressing and antimicrobial film, enhances catheter security (reducing friction-induced displacement risk) while minimizing mechanical damage through precise angle control (fixation angle of 15°-30°).[10] Although the sandwich fixation technique reduced accidental removal (1.0% *vs.* 8.0%), the increased bulkiness of foam dressings may theoretically elevate catheter displacement risk in agitated neonates. Future studies should evaluate fixation strength dynamics.

Importantly, the study revealed comparable skin damage rates between groups, indicating that the novel dressing maintains secure fixation without exacerbating cutaneous adverse effects. As far as safety outcomes are concerned, while no cases of puncture site infections were reported in either study group, the observation group demonstrated a significantly lower overall incidence of adverse

events compared to the conventional group, underscoring the clinical advantages of implementing a comprehensive protective system. Regarding infection control measures, the antimicrobial-impregnated dressing establishes continuous 24 h bactericidal protection at the catheter insertion site through sustained release of chlorhexidine, the efficacy of which has been validated by in vitro experiments.[11] Conventional transparent dressings, by comparison, provide only physical barrier protection and demonstrate reduced effectiveness in preventing microbial growth in moist conditions after bathing. For hemorrhage management, the biocompatible silicone foam dressing not only absorbs exudate to form a gel-like protective layer but also lowers the catheter's pressure on the vascular wall through its pressure-distributing properties, thereby effectively minimizing mechanical bleeding.[12] As for the dynamic maintenance strategy, adjusting the frequency of dressing changes based on individualized risk assessment (e.g., 48 h changes for high-risk pediatric patients) avoids both mechanical damage from excessive intervention and infection risks caused by prolonged dressing use. For bathing, the waterproof breathable membrane used in the indwelling needle management method has certain hydrophobic characteristics, which can effectively block the penetration of water molecules and maintain the stability of humidity in the microenvironment below the dressing. This breaks through the limitations of traditional waterproof and breathable membranes that can only physically isolate water and achieve precise protection in dynamic environments. Finally, the simultaneous enhancement of nursing protocol adherence rates in the observation group further validates the clinical practicality of this FCINM model. Through the implementation of predictive interventions (e.g., pre-bathing catheter protection with polyethylene film) combined with standardized protocols (the "four-step monitoring technique"), the complexity of nursing procedures was significantly simplified. This operational optimization was also evidenced by the reduced catheterization duration observed in the observation cohort.

Based on the results of this study, we will formulate the "Operation Manual of full-cycle management of neonatal intravenous indwelling needle" to clarify the specific operation standards of the three modules of evaluation (before, during and after puncture), intervention (dressing upgrade and dynamic maintenance) and monitoring (infection/bleeding indicators). It is recommended to incorporate the "sandwich" fixation method into the routine nursing process, standardize the "tension-free paste method" and the frequency of dressing change. Through the above transformation strategies, research results can be systematically embedded in clinical practice, and the transformation of neonatal intravenous therapy from experience-driven to evidence-based can be promoted, ultimately achieving the coordinated improvement of safety, efficiency and economic benefits.

It is worth noting that despite the remarkable results of indwelling needle management in this study, long-term use of antimicrobial dressings may still lead to the risk of drug-resistant bacteria colonization, so we recommend changing the type of dressing every 7 days. At the same time, the high cost of silicone foam dressing may not be conducive to the implementation in primary medical institutions. In the future, we can further explore the application effect of iodopor gauze combined with hydrocolloid dressing, so as to improve the clinical applicability of indwelling needle management. Finally, very low birth weight infants (<1500g) are a group that deserves special attention. Since the thickness of the cuticle of the skin is only 1/10 of that of adults, the fit of the dressing still needs to be further verified. At the same time, the long-term effect of catheter-related bloodstream infection was not evaluated because of the lack of long-term follow-up (only observed until 72 h after needle removal). These limitations need to be improved by further research. In the future, we will need to enroll more cases and perform further block randomization and stratified randomization to verify the effect of FCINM in all types of neonates.

To summarize, the FCINM approach significantly enhances the application effectiveness of venous indwelling needles in neonates. Its innovation goes beyond technical integration, creating a nursing model tailored to neonates' physiological traits.

Conflicts of interest

The authors report no conflict of interest.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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