Journal of Intensive and Critical Care
ISSN:2471-8505

Open access Research Article

Effect of an Evidence-based Nursing Education Program on Peripheral Intravenous Infiltration and Extravasation Rates among Neonates

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ABSTRACT

Background: Infiltration and extravasation are the 2 most common complications of intravenous therapy, particularly in critically ill neonates, because of their small veins, fragile skin, and low birth weight, with 8 peripheral IV incidences occurring before this study. This study aimed to determine the effect of using an evidence-based nursing education program on Peripheral IV (PIV) infiltration and extravasation rates among critically ill neonates and the satisfaction, knowledge, and skill levels of nurses in the prevention of PIV infiltration and extravasation.

Methods: This quasi-experimental design study was conducted on staff nurses working in the Neonatal Intensive Care Unit (NICU) of King Saud Medical City, Riyadh, kingdom of Saudi Arabia. The levels of knowledge of 117 staff nurses were assessed. Furthermore, the satisfaction and skill level in preventing PIV infiltration and extravasation were also determined. Consequently, the PIV rates of infiltration and extravasation were compared before and after the implementation of the education program to measure its effectiveness.

Results: The results showed no significant differences ($p=0.25$) in peripheral IV rates before and after education intervention, although the incidences were reduced from 8 to 4. However, after conducting the educational program, all nurses (100%) showed a significant increase in knowledge scores ($M=19.0$, $SD=1.1$) ($p<0.001$). Performance classifications revealed that 16 (17.6%) nurses had average skills and 75 (82.4%) had good skills. The staff satisfaction rates for the overall quality of the evidence-based nursing education program were excellent, very good, and good in 56.4%, 35.9%, and 7.7% of cases, respectively.

Conclusion: PIV infiltration and extravasation can be prevented and treated, and nurses play a vital role in the care and management of intravenous accesses, especially in critically ill neonates. The implementation of evidence-based nurse education guidelines on PIV infiltration and extravasation, such as the S.T.I.C.K Bundle, can improve the knowledge and skills of nurses in ensuring that intravenous therapy remains safe and critically ill neonates are free from infiltration and extravasation.

Keywords: Infiltration; Extravasation; Evidence-based learning; Peripheral IV

Received:	01-February-2024	**Manuscript No:**	IPJICC-24-19009
Editor assigned:	05-February-2024	**PreQC No:**	IPJICC-24-19009 (PQ)
Reviewed:	19-February-2024	**QC No:**	IPJICC-24-19009
Revised:	26-February-2024	**Manuscript No:**	IPJICC-24-19009 (R)
Published:	04-March-2024	**DOI:**	10.35248/2471-8505-10.1.01

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Citation Haimour AF, Leonardo MC, Bhasker D, Rivero K, Alvarado JR, et al. (2024) Effect of an Evidence-based Nursing Education Program on Peripheral Intravenous Infiltration and Extravasation Rates among Neonates. J Intensive Crit Care. 10:01.

ABBREVIATIONS

(PIV) Peripheral Intravenous; (NICU) Neonatal Intensive Care Unit; (S.T.I.C.K) Securement, Touch look and compare, Irritant, Catheter selection, Keep it

INTRODUCTION

Among critically ill neonates, Intravenous (IV) therapy is an indispensable component in the delivery of fluids, nutrition, and medications, especially in the context of gastrointestinal immaturity and absorption problems because of common pathophysiological pathways [1]. However, as with any other medical interventions and in consideration of the anatomically small veins of neonates, IV therapy carries its own risks and hazards that can result in adverse events such as pain, tissue and nerve damage, and even loss of function of the affected extremity [2]. Therefore, it is imperative that IV lines of neonates are closely monitored and regularly assessed, and early interventions are instituted when accesses are no longer patent or viable [3].

Two of the most common complications of IV access are infiltration and extravasation [4]. While both injuries refer to the unintended leakage of fluid from within blood vessels to surrounding tissues, infiltration refers to the leakage of non-vesicant fluid, such as normal saline or dextrose 5%, and extravasation refers to the leakage of vesicant fluid, such as antimicrobial and chemotherapeutic agents [5]. Infiltration can cause localized swelling and pain on flushing or medication administration into the affected IV access, whereas extravasation can cause severe tissue damage, necrosis, and compartment syndrome in severe cases [6]. Extravasation injuries can occur even when accesses are located in large blood vessels such as umbilical veins or in peripherally inserted central catheters [7]. In a study by Fonzo-Christe C, et al. the incidence and prevalence of extravasation injuries among neonates were approximately 12.6 per 100 intravenous catheter days and 38 per 1,000 neonates, respectively [8].

While patient-specific factors such as prematurity, low birth weight, active limb movements, and age of IV lines from the time of insertion increase the risk of infiltration and extravasation in critically ill neonates, competencies of healthcare professionals in the use, care, management, and monitoring of IV lines play a significant role in maintaining the health and integrity of blood vessels used for IV therapy and in the prevention, early identification, and timely intervention to reduce the incidence of such injuries [9]. As healthcare professionals tasked with administering fluids and medications through IV lines, nurses have a crucial role in ensuring that critically ill neonates do not develop infiltration and extravasation and that early treatment is implemented to prevent further harm and injury to surrounding tissues in case they develop them [10]. When nurses are being trained and educated to improve their competencies in IV access management, the rates of infiltration and extravasation were found to be significantly reduced [11].

However, to the best of our knowledge, only a few studies have evaluated the effectiveness of evidence-based programs for infiltration and extravasation prevention in Neonatal Intensive Care Units (NICUs). In addition, where evidence was available, previous studies only measured competency-focused outcomes but did not measure patient-specific outcomes such as the actual rates of infiltration and extravasation. Moreover, some recommendations from evidence-based guidelines developed by international specialty organizations (such as the Infusion Nurses Society and the Association for Vascular Access) have not been integrated into training programs provided to nurses in clinical settings. Given the physical, economic, and legal implications of infiltration and extravasation injuries, examining the effectiveness of training programs in the reduction of such injuries can significantly contribute to the safety and quality of IV therapies for critically ill neonates [12].

Aims

This study aimed to answer the following questions:

1. What is the effect of using an evidence-based nursing education program on peripheral IV (PIV) infiltration and extravasation rates among critically ill neonates?
2. What is the effect of using an evidence-based nursing education program on the satisfaction, knowledge, and skill performance levels of nurses in the prevention of PIV infiltration and extravasation?

Review of the Literature

Evidence from the literature is clear on the need to institute strategies for the prevention, early recognition, and appropriate treatment of PIV infiltration and extravasation injuries. Kim JY, et al. shared a detailed strategy to prevent extravasation and recommended measures for handling drugs known to cause tissue necrosis [4]. Health professionals must be aware of extravasation management standard guidelines to avoid the outcome. Healthcare professionals should regularly check the availability and completeness of the extravasation kit, assess patients' sensory changes (e.g., tingling or burning), and always pay attention to patient reports. In addition, continuous education on extravasation is substantial and is expected to reduce the incidence of extravasation and contribute to patient care improvement. Similarly, Bhunia D, et al. emphasized the prevention of PIV infiltration and extravasation by the early identification of risk factors, proper IV care, implementation of IV therapy protocols, and close supervision of IV lines [13]. When a multi-method education program was implemented, nurses demonstrated better performance in the prevention of infiltration and extravasation injuries.

Following on the effectiveness of evidence-based training programs, Elrazek AA, et al. found that implementing guidelines for the prevention and management of PIV infiltration and extravasation significantly increased nurses' knowledge and practices and lowered the incidence rates of PIV infiltration and extravasation among neonates [14]. In addition, Chan KM, et al. found that the implementation of evidence-based clinical practice guidelines significantly reduced PIV infiltration and extravasation among neonates in a controlled before-and-after study [15]. To maintain an increase in nurse knowledge and adherence, educational programs on the clinical practice guidelines should be conducted regularly, and they should be integrated into induction programs for nurses. The need for educational programs is further reinforced by a descriptive,

cross-sectional study conducted by Gassmalla HM, et al. who found that nurses had low levels of knowledge regarding the prevention of PIV infiltration and extravasation [6].

Theoretical Framework

Kirkpatrick's Levels of Evaluation Model provides a useful framework for categorizing evaluations of educational interventions [16]. The 4 levels of evaluation described in the framework are (1) reaction, (2) learning, (3) behaviour, and (4) outcomes [17]. At the reaction level, evaluation outcomes include affective (whether participants liked the education program) or instrumental (whether participants found the training useful) characteristics. At the learning level, evaluation outcomes involve attitudes (feeling), knowledge (knowing), or skills (doing). Evaluation at the behavior level (transfer of skills to real clinical settings) and outcome level (patient care results) is not commonly completed in nursing education because these studies are more complex and expensive to conduct [18].

METHODS

Design

In this study, we employed a quasi-experimental research design that focused on determining the effect of an evidence-based nursing education program on the prevention of PIV infiltration and extravasation among neonates. Specifically, the design involved data comparisons of PIV infiltration and extravasation rates obtained before and after the implementation of the education program.

Setting

The study was conducted in NICUs of King Saud Medical City (KSMC), Riyadh, Saudi Arabia. The participating hospital site has a bed capacity of 69. KSMC is a level 3 referral centre that provides comprehensive service to sick and premature neonates.

Participants

All 148 nurses working in NICUs were invited to participate in the study. No specific sampling techniques were performed.

Data Collection and Measurement

1. Research Intervention: The nurse education program was adopted from the Infusion Nursing Society guidelines (2021) and included the following elements:

- Pediatric/neonatal infiltration and extravasation, risk factors, and symptoms;
- Medications and fluid lists that have a greater risk of infiltration/extravasation development and special antidotes;
- Assessment scales for infiltration/extravasation;
- Machine training on IV infusion pumps;
- Intravenous catheter securement; and
- Wound care-related subjects

1. The training was conducted for 3 consecutive days in June 2022, utilizing different teaching strategies (including simulation training, demonstration, return demonstration, use of audiovisual materials, and gamification). A prior arrangement has been made with the hospital site to ensure the participation of nurses within specific times.
2. Participants were asked to fill out an information sheet that asked for socio-demographic characteristics (i.e., sex, age, educational preparation, and years of nursing experience).
3. Participants answered a 5 item questionnaire using a 5 point Likert scale after the education program to determine levels of satisfaction.
4. Participants' knowledge before and after the educational program was measured using a pre-test–post-test questionnaire. The questionnaire consisted of 20 multiple-choice questions developed by the researchers and validated for content by 2 practice experts in the field of interest.
5. Staff practices were monitored in NICUs to assess the application of what they had learned using the quality improvement pediatric IV infiltration prevention mnemonic bundle "S.T.I.C.K" (S for Securement, T for TLC (Touch, Look, Compare), I for Irritants, C for Catheter Selection (type, size, location), and K for Keep it? (daily review of necessity)). This bundle has been shown to improve staff practices relevant to the prevention of PIV infiltration and extravasation rates [19]. Monitoring lasted over 4 months (i.e., July to October of 2022). Each participant was assessed thrice for which they obtained a score of one if the bundle was performed and 0 if the bundle was not performed. Nurses had excellent performance if they obtained a score of 11-15 (70%-100%), satisfactory performance if they obtained a score of 6-10 (50%-69%), and poor performance if they obtained a score of 1-5 (<50%).
6. Rates of PIV infiltration and extravasation were measured 6 months before (January to June of 2022) and 6 months after (July to December of 2022) the implementation of the education program. Rates were calculated based on staff-reported occurrence variance accident reports. The rate was calculated by unit and displayed as the number of infiltration events per 1,000 patient days. The benchmark for this indicator was obtained from the National Database of Nursing Quality Indicators (NDNQI) based on the organization's bed capacity and services offered. This benchmark was used to compare PIV infiltration and extravasation incidence rates among departments within the organization (**Figure 1**).

Ethical Considerations

Ethical approval was granted by the relevant institutional review boards. Permission to use the tools in the study was obtained. The data of participants were handled anonymously. Data were kept confidential and were only accessed by the research team. Informed consent was obtained from each participant.

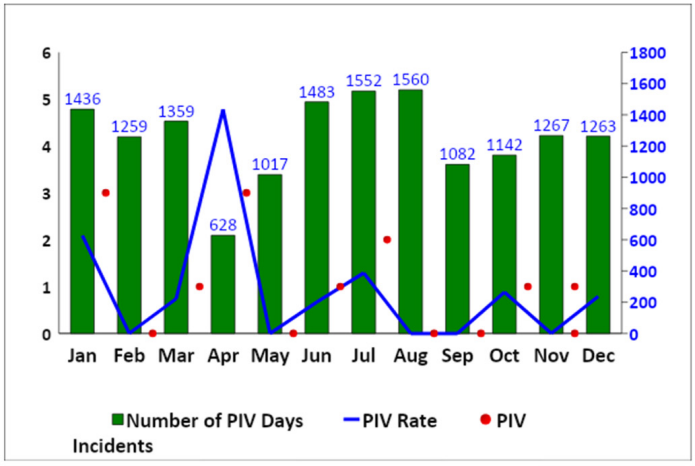

Figure 1: PIV Rate per 1000 PIV days in NICU (January to December of 2022)

RESULTS

Statistical Analysis

Data were analysed using SPSS (version 25.0; IBM, Armonk, NY, USA) for Windows. Pre-test and post-test knowledge scores were converted to percentages and classified as "Inadequate Knowledge" if they were <50% and "Adequate Knowledge" if they were ≥ 50%. On the other hand, performance was given a score of 0 if the test was not performed and 1 if performed against each criterion of the S.T.I.C.K. bundle of practice and was summed for a maximum score of 15. The association between knowledge and performance scores was measured using the chi-square test. As the scores were skewed, the Mann-Whitney U test was used to identify statistically significant differences between the mean rank values of the departments (i.e., NICU2 and NICU3). The Kruskal-Wallis test was used to measure significant differences among at least 3 categories (i.e., clinical experience). The Spearman coefficient of correlation was used to test whether a significant relationship existed between knowledge and performance scores. The threshold for statistical significance was set at p<0.05 (**Figure 2**).

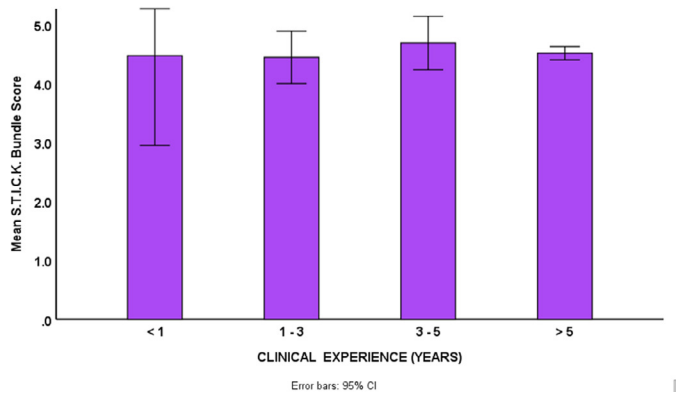

Figure 2: Mean S.T.I.C.K. Bundle scores for clinical experience in the NICU

A total of 117 nurses participated in the nurse education program. These staff were assessed for knowledge scores and answered a 5-item questionnaire to determine their level of satisfaction with the program. However, only 102 nurses were assessed for skill scores for various reasons (e.g., nurses did not have direct patient care such as head nurses, nurses were on annual leave and maternity leave at the time of skill measurement, nurses were transferred to another department, etc.). **Table 1** shows the sociodemographic characteristics of the participants. All participants were female. The majority of the participants were 25 years-34 years old (50.4% in the knowledge group and 49% in the skills group), followed by those who were 35 years-44 years old (34.2% in the knowledge group and 34.3% in the skills group). Regarding their academic qualifications, the majority of them had an undergraduate degree (80.3% in the knowledge group and 80.4% in the skills group). Finally, the majority had more than 5 years of relevant clinical experience in pediatrics (82.9% in the knowledge group and 83.3% in the skills group).

Table 1: Demographic characteristics of participants

Variables	KNOWLEDGE Assessment (N=117)		STICK Bundle Assessment (N=102)*	
Gender				
Female	117	100%	102	100%
Age (years)				
18-24	1	0.90%	1	1%
25-34	59	50.4%	50	49%
35-44	40	34.2%	35	34.3%
≥ 45	17	14.5%	16	15.7%
Level of Education				
Diploma degree	22	18.8%	19	18.6%
Bachelor's degree	94	80.3%	82	80.4%
Master's degree	1	0.90%	1	1.00%
Clinical experience in NICU (years)				
0 to <1	5	4.30%	3	2.90%
1 to <3	5	4.30%	5	4.90%
3 to <5	10	8.50%	9	8.80%
>5	97	82.9%	85	83.3%

Note: Participants in STICK bundle skill assessment

The 5-item instrument used to determine the level of satisfaction of the staff nurses has 5 questions with a 5-point Likert scale: For questions 1 to 4, (1) Strongly Agree, (2) Agree, (3) Neutral, (4) Disagree, and (5) Strongly Disagree; For question 5, (1) Excellent, (2) Very good, (3) Good, (4) Fair, and (5) Poor. The following questions were asked: (1) The training campaign met my expectations; (2) The learning objectives for each training booth were identified and followed; (3) Adequate time was provided for questions and discussions; (4) This training campaign accommodated your background and needs, and (5) Rate the overall quality of the training campaign. **Tables 2 and 3** show the percentages of responses that resulted from the 5 item instrument. In question 1, 53% of the staff answered "Strongly Agree," 45.3% answered "Agree," and 1.7% answered "Neutral." In question 2, 50.4% of the staff answered "Strongly Agree," 48.7% answered "Agree," and 0.9% answered "Neutral." In question 3, 45.3% of the staff answered "Strongly Agree," 53% answered "Agree," and 1.7% answered "Neutral." In question 4, 44.4% of the staff answered "Strongly Agree," 53.8% answered "Agree," and 1.7% answered "Neutral." Lastly,

in question 5, which determines overall satisfaction, 56.4% of the staff answered "Excellent," 35.9% answered "Very good," and 7.7% answered "Good" (Figures 3 and 4).

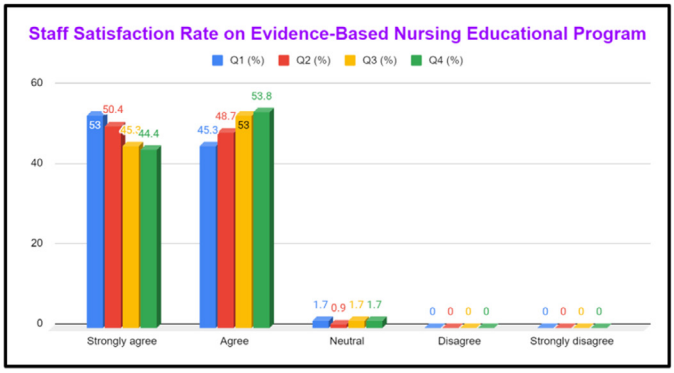

Figure 3: Staff satisfaction rate on the Evidence-Based Nursing Educational Program (n=117)

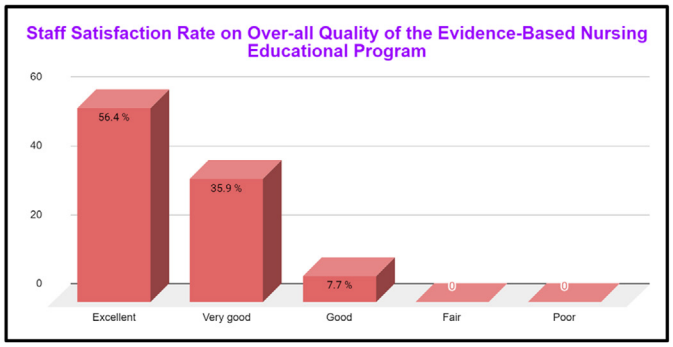

Figure 4: Staff satisfaction rate on overall quality of the Evidence-Based Nursing Educational Program (n=117)

Table 2: Staff Satisfaction Rate on the Evidence Based Nursing Educational Program (n=117)

	Q1 (%)	Q2 (%)	Q3 (%)	Q4 (%)
Strongly Agree	53	50.4	45.3	44.4
Agree	45.3	48.7	53	53.8
Neutral	1.7	0.9	1.7	1.7
Disagree	0	0	0	0
Strongly Disagree	0	0	0	0

Table 3: Staff Satisfaction Rate on Overall Quality of the Evidence-Based Nursing Educational Program (n=117)

	Q5 (%)
Excellent	56.4
Very good	35.9
Good	7.7
Fair	0
Poor	0

During the pre-test, only 10 (8.5%) demonstrated adequate knowledge scores (M=6.34, SD=2.3). After undergoing the education program, all nurses (100%) showed a significant increase in knowledge scores (M=19.0, SD=1.1) (p<0.001). In terms of performance, while 102 nurses were assessed for skills, only 91 completed all 3 scheduled skill assessment sessions, and 11 of them were excluded due to their unavailability. Performance classifications showed that 16 (17.6%) nurses had average skills and 75 (82.4%) had good skills. Table 4 shows the scores for the knowledge and skills of nurses.

Table 4: Performance level on S.T.I.C.K. Bundle criteria (n=91)

Performance Level	S.T.I.C.K. Bundle criterion				
	Secur-ement	TLC	Irritant	Catheter Selection	Keep It
Poor	9 (9.9%)	2 (2.2%)	0	0	0
Average	47 (51.6%)	21 (23.1%)	10 (11%)	4 (4.4%)	8 (8.8%)
Good	35 (38.5%)	68 (74.7%)	81 (89%)	87 (95.6%)	83 (91.2%)

The 91 staff that completed the 3 scheduled skill assessment sessions were assessed using each criterion of the S.T.I.C.K. bundle. As a result, the S (securement) has p=0.162, the TLC (touch, look and compare) p=0.124, the I (irritant) p=0.976, the C (catheter selection) p=0.545, and the K (keep it) p=0.103 (Table 5).

Table 5: S.T.I.C.K. Bundle scores (n=91)

S.T.I.C.K. Bundle Total Scores	NICU 2	NICU 3	P-Value
	MEAN RANK		Good
Securement	41.7	48.8	0.162
TLC	42	48.6	0.124
Irritant	45.9	46	0.976
Catheter selection	46.7	45.5	0.545
Keep it	48.7	44.2	0.103
Stick bundle	43.8	47.4	0.507

There were 8 PIV incidents from January to June of 2022, with 7182 PIV days contributing to a PIV rate of 1.11/1000 PIV days. On the other hand, there were 4 PIV incidents from July to December of 2022, with 7866 PIV days contributing to a PIV rate of 0.51/1000 PIV days. Even though the number of PIV incidents decreased in the second half of 2022, Fisher's exact test showed no statistically significant differences (p=0.25) in PIV rates before and after the educational intervention (Figure 5).

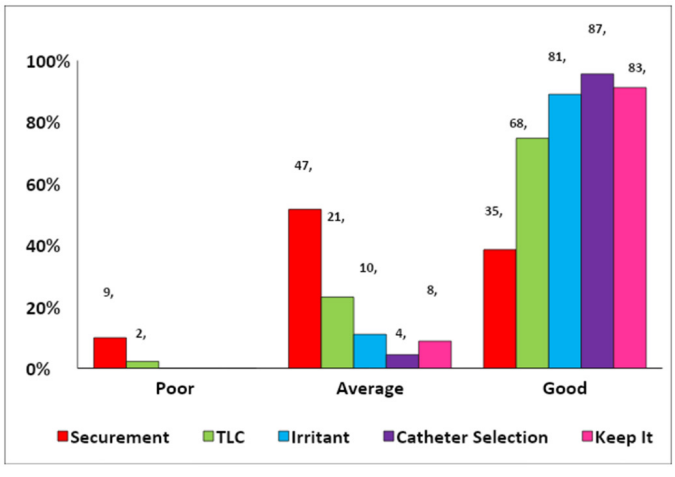

Figure 5: Performance level of 91 nurses on S.T.I.C.K. bundle

DISCUSSION

The results of the study showed that nurses working in NICUs in the participating hospital site in Saudi Arabia demonstrated similarly low levels of knowledge on the prevention and management of PIV infiltration and extravasation among critically ill neonates [6,10,20,21]. This is crucial as nurses are at the forefront of using IV lines for fluid management and nutritional therapy, and critically ill neonates are particularly predisposed to infiltration and extravasation injuries owing to their small veins, low birth weight, and fragile skin [22,23]. Our findings have another significant implication: Despite increasing awareness of the relevance of safe and quality IV therapy, low levels of knowledge persist among nurses, reflecting the need for the implementation of regular educational and teaching programs to reinforce knowledge and the adoption of best practice guidelines and patient pathways for the administration of IV therapies [24-26].

The implementation of the education program was associated with significant improvements in knowledge scores, similar to other studies that tested the effectiveness of such programs [6,14,22]. However, the critical point is that there should be regular and consistent implementation of the educational program, especially when considering that knowledge is not a static variable as it can decrease over time if it is not refreshed and updated [20]. Studies have recommended that education programs should be designed sustainably to ensure that nurses can continue to access regular and consistent training even after the completion of the research study [4,25,27]. Moreover, education programs should have a psychomotor (i.e., skill) component to ensure that knowledge is translated into skills and that knowledge will not remain as information only [28,29]. In issues such as infiltration and extravasation injuries that are significantly associated with practical competencies, nurses should not only learn what to know in the prevention of such injuries but also what to do to prevent their occurrence and how to act in terms of timely treatment when such injuries occur [30,31].

No significant differences were found in measured PIV rates before and after the education program, which contrasts with the findings of other studies. This result suggests that improvements in knowledge scores do not necessarily translate to improvements in practice and that factors other than knowledge significantly influence PIV rates [23]. The identification of such factors (i.e., patient, professional and organizational-specific factors) can be explored in future studies that aim to prevent and manage PIV infiltration and extravasation injuries among critically ill neonates.

Nevertheless, this study has some limitations. 1st, it was conducted in only a single hospital in Saudi Arabia, thus limiting the generalizability of its results. 2nd, there was a significant reduction in the number of nurses who were initially eligible to be assessed for skills and in the number of nurses who completed all 3 sessions of skills assessment. 3rd, while PIV rates were measured monthly over twelve months, there was no similar monthly measurement of knowledge and skill levels that could have provided data on whether scores fluctuated with increments in PIV rates or whether scores remained high throughout the data collection period.

CONCLUSION

IV therapy is a life-saving measure for critically ill neonates because it allows not only the administration of emergency and essential medications but also the delivery of nutritional products to meet the requirements for growth and development. Therefore, it is crucial that preventable and treatable complications such as infiltration and extravasation are avoided, identified, and treated promptly. Nurses play a critical role in the care and management of IV lines among critically ill neonates. Implementing evidence-based nurse education guidelines can contribute to the improvement of knowledge and skills of nurses to ensure that IV therapy remains safe and effective and also that critically ill neonates are free from harm and injury arising from infiltration and extravasation incidents.

ACKNOWLEDGMENT

- We appreciate the help and support of the following persons who, in 1 way or another, facilitated our study.
- Dr. P.J. Parameaswari, PhD (Biostatistics consultant) shared her knowledge and helped in data analyses and statistical computations.
- Ms. Margarita Van Wyk (Pediatric Hospital director of Nursing) for her unwavering support, guidance, valuable comments, suggestions, and provisions.
- The Research and Innovation Center, King Saud Medical City, for their support in editing and formatting our manuscript.
- Finally, we thank all the people who directly or indirectly facilitated the completion of our work.

CONFLICT OF INTEREST

The Authors declared that there is no conflict of interest.

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