Nursing: Research and Reviews

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ORIGINAL RESEARCH

Development and Effectiveness of a Central Venous Catheter Management Education Program for Nurses in Hematology-Oncology Wards

Soohee Park[1], Jihyun Kim[2]

[1]Department of Nursing, Eulji University Hospital, Daejeon, Republic of Korea; [2]Department of Nursing, Daejeon University, Daejeon, Republic of Korea

Correspondence: Jihyun Kim, Department of Nursing, Daejeon University, 62, Daehak-ro, Dong-gu, Daejeon, 34520, Republic of Korea, Tel +82-42-280-4651, Fax +82-42-280-2785, Email jheyelin@dju.kr

Purpose: This study aimed to develop and implement a central venous catheter (CVC) management education program for nurses in hematology-oncology wards and evaluate its effects on CVC-related knowledge, performance, empowerment, and central line-associated bloodstream infection (CLABSI) rates.

Methods: A total of 46 nurses from two university hospitals in South Korea participated. The program was developed using the ADDIE instructional model and implemented over a four-month period. Outcome measures included knowledge and performance in CVC and hub management, empowerment, and CLABSI rates.

Results: Post-intervention analysis showed significant improvements in CVC management knowledge (t=3.42, p=0.001), CVC performance (t=4.37, p=0.000), hub management performance (t=2.64, p=0.011), and empowerment (t=3.40, p=0.001). No significant differences were found in hub management knowledge (t=0.88, p=0.382) or CLABSI rates (X^2=2.00, p=0.157).

Conclusion: The CVC management education program developed in this study was found to be effective in significantly improving nurses' knowledge, performance, and empowerment related to CVC and hub management in hematology-oncology wards. However, there was no statistically significant reduction in the rate of CLABSIs. This suggests that CVC management is influenced by a multidisciplinary clinical environment involving various healthcare professionals beyond nurses. Therefore, future interventions aimed at reducing infection rates should incorporate a multidisciplinary approach in addition to nurse education.

Keywords: central venous catheter, nurse, education, knowledge, infection

Introduction

Central venous catheters (CVCs) are commonly used in critically ill patients for various purposes, such as chemotherapy administration, emergency hemodialysis, intravenous fluid therapy, parenteral nutrition, and blood transfusions.[1] However, CVC insertion is associated with major complications in more than 3% of cases, including infections, thrombosis, pneumothorax, hemothorax, and mechanical issues, such as catheter occlusion.[2]

Patients with hematologic malignancies frequently require CVCs because of ongoing chemotherapy, transfusions, medication administration, fluid replacement, and frequent blood sampling, resulting in an increased incidence of CVC-related complications.[3] Among these complications, central line-associated bloodstream infections (CLABSIs) are particularly significant, accounting for approximately 35% of healthcare-associated deaths and contributing to increased healthcare costs, prolonged hospital stays, and elevated morbidity and mortality rates.[4] Recent multicenter studies have shown that hematology–oncology patients experience a higher incidence of CLABSI, ranging from 3 to 5.2%, due to frequent catheter access and immunosuppression related to chemotherapy.[5] The Centers for Disease Control and Prevention (CDC) emphasize standardized hub care, aseptic techniques, and staff education as essential strategies to prevent CLABSI.[6] However, few studies have examined the implementation of these evidence-based practices within Korean hematology–oncology settings.

https://doi.org/10.2147/NRR.S546043
Received: 10 June 2025
Accepted: 23 January 2026
Published: 5 February 2026

Nurses in hematology-oncology wards play a pivotal role in the insertion, maintenance, and management of CVCs. As they are directly involved in invasive procedures, such as intravenous injections, it is critical that they possess a comprehensive understanding of and adhere to the guidelines for CLABSI prevention and management.[3] In fact, when nurses followed evidence-based infection control protocols, CLABSI incidence decreased by 48–78%, leading to shorter hospital stays and reduced healthcare expenditure.[7,8]

Although the Korea Disease Control and Prevention Agency (KDCA) provides standard infection control guidelines,[9] these primarily focus on general infection prevention and lack detailed protocols for comprehensive CVC management, particularly regarding the recently emphasized aspect of hub care. In contrast, the Centers for Disease Control and Prevention (CDC) emphasize standardized hub care, aseptic techniques, and staff education as essential strategies for preventing CLABSI.[5] This discrepancy highlights the need to develop educational and clinical practice guidelines that integrate internationally recognized standards of hub management into the Korean healthcare context. To improve clinical adherence to CVC-related protocols, the use of CVC bundles—comprising insertion and maintenance bundles, including hub disinfection—has been advocated.[10] Despite the clinical importance of hub management in CVC care and infection prevention, few studies have assessed nurses' performance or evaluated the effectiveness of related educational interventions. Therefore, educational programs on CVC management should encompass the entire scope of catheter use, including insertion, maintenance, removal, infection control, and hub care. Current educational materials are insufficient and lack systematic phase-specific management strategies and detailed infection control procedures. There is a pressing need for educational programs that are comprehensive and practically applicable in clinical settings.

Ongoing and repeated training is essential for improving nurses' knowledge, awareness, and performance in CVC care.[10–12] Education should be structured according to the stages of catheter use and should incorporate hub care, which is increasingly critical from an infection prevention perspective. Therefore, we aimed to develop and implement a CVC management education program, including stage-specific infection control and hub management, for nurses working in hematology-oncology wards, and to evaluate its effectiveness.

Aim

We aimed to develop and implement a CVC management education program for nurses working in hematology-oncology wards and to examine its effects on the knowledge of CVCs and hub management, performance in CVC and hub management, empowerment, and rate of CLABSIs.

Study Hypotheses

The experimental group that receives the CVC management education program will demonstrate greater knowledge and performance in CVC and hub management and higher levels of empowerment compared with the control group; In addition, the experimental group will demonstrate lower rates of CLABSIs following the intervention.

Materials and Methods

Study Design

This study adopted a non-equivalent control group pretest-posttest design to develop a CVC management education program targeting nurses in hematology oncology wards and evaluate its effectiveness. This study was conducted in two phases. The first phase involved program development based on the Analysis, Design, Development, Implementation, Evaluation (ADDIE) instructional model. The second phase involved the implementation of the program and assessment of its effectiveness.

Study Population

The study involved nurses from the hematology-oncology wards of two university hospitals (Eulji University Hospital 1,2) in Daejeon and Uijeongbu, two cities of similar size, who had not received central venous catheter (CVC) management education in the past month. The sample size was determined using G*Power 3.1.9.7 software. Based on a previous study that examined the effect of an infection control education program on nurses' knowledge and

performance,[13] the sample size was calculated based on a significance level (α) of 0.05, power (1-β) of 0.80, and *t*-test, and the minimum sample size was calculated to be 42. To account for a 20% dropout rate, 50 participants were initially recruited. After excluding 4 participants who missed one or more sessions, 46 participants remained in the study.

Ethical Considerations

This study was approved by the Institutional Review Board of the Eulji University Hospital in Daejeon City (approval no. EMC202307005001-HE004). Participants were informed of their right to withdraw at any point without penalty and that their data would be used solely for research purposes. Confidence and anonymity were ensured, and written informed consent was obtained from all participants prior to data collection.

Instruments Used in the Study

Knowledge of CVC Management

Knowledge of CVC management was assessed using a tool originally developed by Ha et al[14] based on the KDCA[9] and CDC[15] guidelines, and later revised by Kim.[16] The instrument consisted of 18 multiple-choice items, and scores were calculated as the percentage of correct responses. Higher scores indicated greater knowledge of CVC management practices. Example items included "During central venous catheter insertion, maximum sterile barrier precautions must be observed, including the use of a cap, mask, sterile gown, sterile gloves, and a large sterile drape that covers the entire body". The Kuder–Richardson Formula 20 (KR-20) reliability coefficient was.68 in the original study where the instrument was developed and.75 in the present study.

Performance in CVC Management

Performance in CVC management was measured using a tool originally developed by Ha et al[14] based on the KDCA[9] and CDC[15] guidelines, and later revised by Kim.[16] The instrument consisted of 15 items rated on a 5-point Likert scale (1 = never performed, 5 = always performed), with higher scores indicating higher levels of self-reported performance. Example items included "If the central venous catheter is no longer needed, the nurse should request its prompt removal by the physician". The original Cronbach's alpha of the instrument was.79, and it was.69 in the present study.

Empowerment

Spreitzer's[17] empowerment scale, revised by Jung,[18] was used to measure empowerment during infection control. It included 12 items rated on a 5-point Likert scale. Higher scores indicated higher levels of empowerment. Its reliability, in terms of Cronbach's alpha, was.72 in Spreitzer's study,0.90 in Jung's study, and.95 in the present study.

Knowledge of CVC Hub Management

Knowledge of CVC hub management was assessed using a questionnaire originally developed by The Joint Commission[19] and Dersa et al[20] and subsequently revised by Oh.[21] The knowledge instrument consisted of 14 multiple-choice items, each with one correct answer. Responses were scored dichotomously (1 = correct, 0 = incorrect), and the knowledge score was calculated as the mean of the total correct responses across the 14 items, resulting in a possible score range of 0 to 14. Higher scores indicated greater knowledge of evidence-based CVC hub management practices.

An example item was: "Disinfection of the central venous catheter hub involves wiping all surfaces of the hub by firmly rubbing and rotating it 360° to ensure that every area is thoroughly cleaned".

The internal consistency reliability of the knowledge scale, assessed using KR-20, was.68 in the original study and.69 in the present study.

Performance in CVC Hub Management

Performance in CVC hub management was measured using a separate performance assessment tool based on the same conceptual framework and item content as the knowledge questionnaire, originally developed by The Joint Commission[19] and Dersa et al[20] and revised by Oh[21]. While the content domains overlapped with those of the knowledge instrument, performance was assessed independently to capture the frequency of actual clinical practice rather than factual knowledge. The performance instrument consisted of 14 items, each rated on a 5-point Likert scale (1 = never

performed, 2 = rarely performed, 3 = sometimes performed, 4 = often performed, 5 = always performed). The total performance score was calculated as the mean of item scores, with higher scores indicating more consistent adherence to recommended CVC hub management practices in clinical settings. The internal consistency reliability of the performance scale, assessed using Cronbach's α, was.76 in the original study and.78 in the present study.

CLABSI Rate

The CLABSI rate was calculated based on cases of patients who had a CVC in place for >2 days and at least one positive blood culture unrelated to infections at other sites or skin commensals identified in ≥2 independent cultures. The number of CLABSI cases was reviewed from medical records of the hospital in which the CVC management education program was implemented. Data were collected exclusively from this hospital for 3 months before and 3 months after program implementation.

The infection rate was calculated as follows:[22] (Number of CLABSI cases/total catheter days) × 1000.

Research Procedure

The study was carried out in two stages: The first phase of the study involved developing CVC management education program based on the ADDIE instructional design model, and the second phase involved implementing the developed program and evaluating its effectiveness.

Development of the CVC Management Education Program

The program was developed based on the ADDIE instructional model by Friedman and Friedman,[23] which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation.

Analysis

To analyze existing education programs for CVC management, a structured review of studies conducted in Korea was performed. The review focused on research and training programs developed and implemented in Korea to reflect the local clinical context of CVC management and infection prevention. Data sources included the Korean National Healthcare-Associated Infections Surveillance System (KONIS),[22] evidence-based clinical practice guidelines from the Korean Hospital Nurses Association,[24] and the Korea Disease Control and Prevention Agency (KDCA).[9] In addition, relevant studies and training materials[3,8,21,25,26] published between 2010 and 2024 were identified through searches of domestic academic databases such as RISS, KISS, and KMbase. Inclusion criteria covered studies addressing CVC education, maintenance, and infection control among nurses.

To complement the literature findings, semi-structured interviews were conducted with nine hematology–oncology nurses and three infection control nurses. Interview data were analyzed thematically to identify educational needs, practical challenges, and gaps in existing guidelines. The results indicated that current Korean guidelines and training programs are largely focused on infection prevention but lack detailed, hub-specific content and comprehensive management procedures.

Design

Based on the literature and interviews, educational goals, media, content, and evaluation strategies were established. The objective was to improve the understanding of CVC concepts and their importance, as well as to enhance infection prevention and stage-specific management (insertion, maintenance, and removal). The program consisted of 6 sessions, each lasting 40–50 min, and was designed for small group settings, to accommodate shift schedules. Lectures using PowerPoint presentations, videos, and hands-on practice were included to enhance learning.

Development

Instructional materials were developed based on the guidelines of the Korean Hospital Nurses Association,[24] KONIS,[22] and KDCA,[9] as well as previous research.[3,8,21,25,26] The content was validated and revised by a panel of experts, including three nursing PhDs, two Advanced practice nurses (APNs) in infection control nursing and oncology with over

10 years of experience., and two hematology-oncology professors. Detailed contents of the CVC management education program are presented in Table 1.

The session topics were:

Session 1: Overview of CVC management

Session 2: CVC insertion management

Session 3: CVC maintenance management

Session 4: Maintenance (including totally implantable venous access device [TIVAD] and hub care)

Session 5: Hands-on hub management training

Session 6: CVC removal management

Implementation

The 6-session program was implemented, with each session lasting 40–50 min. The training included lectures (PowerPoint), videos, and practical training. Hands-on hub care training included demonstrations and individual skill feedback.

Table 1 Details of CVC Management Education Program

Session	Topic	Content	Method (Duration)
1	Overview of CVC Management	• Necessity and definition of CVC management • Types and characteristics of CVC • Current status and risks of catheter-related infections	Lecture (50 min)
2	CVC Insertion Management	• Pre-insertion preparation (patient selection, site selection, preparation processes) • Procedures during insertion, confirmation post-insertion • Infection control during insertion (Central line bundle)	Lecture & Demonstration (50 min)
3	CVC Maintenance Management	• Definition, diagnostic criteria, risk factors, and prevention strategies for CLABSI • General infection control and hub management practices (medication administration, blood transfusion, sampling) • Dressing practices at insertion sites • Prevention and management of catheter dislodgement	Lecture & Demonstration (50 min)
4	Maintenance (including totally implantable venous access device [TIVAD] and hub care)	• General principles and structural understanding of chemoports • Infection control, needle insertion/removal, medication administration, blood sampling, heparin injection • Management of common chemoport issues (functional abnormalities, obstruction, usage precautions)	Lecture & Demonstration, Practice (50 min)
5	Hands-on Hub Management Training	• Practical session focused on chemoport hub management and infection control	Lecture & Demonstration, Practice (50 min)
6	CVC Removal Management	• Pre-removal assessment and procedure • Management of complications (local/systemic infections, obstruction) • Procedures for suspected infections including blood culture tests	Lecture & Demonstration (50 min)

Abbreviation: CVC, central venous catheter; CLABSI, central line-associated bloodstream.

Evaluation

Preintervention and postintervention evaluations were conducted using self-report questionnaires to assess knowledge, performance, and empowerment. The CLABSI rates were evaluated by reviewing medical records.

Implementation of the CVC Management Education Program

The CVC management education program was implemented in small groups consisting of 4 to 6 participants, considering the effectiveness of training and the nurses' shift work schedules. To ensure consistency in the delivery of content, all sessions were conducted by the same researcher using standardized lesson plans and materials to maintain instructional uniformity and internal validity.

Each of the six sessions, lasting 40–50 minutes, included lectures with PowerPoint presentations, videos, and hands-on practice. The practical training focused on CVC hub management, particularly in the context of TIVAD use and infection control, and included educational videos, demonstration sessions, and one-on-one feedback on each participant's procedural skills. Although direct observation of clinical performance was not included, participants received post-session feedback through discussions and were encouraged to apply the acquired knowledge in their daily practice. After completion of the study, the developed education program was also provided to both the experimental and control wards to promote continued practice improvement and facilitate implementation in real clinical settings.

Data Collection Methods

For this study, data was collected from July 10, 2023, to February 21, 2024. The preintervention survey was conducted 1 week before the start of the program, and the post-intervention survey was conducted 1 week after the completion of the program. Each participant took approximately 10–15 min to complete the self-administered questionnaires collected by the researcher.

Data on CLABSI rates were obtained from a review of medical records at the hospital where the experimental group was located. All central venous catheter–associated infection cases that occurred in the hematology-oncology ward during the 3-month period before and the 3-month period after the implementation of the CVC management education program were included in the analysis. No randomization was performed; the intervention was applied to one hospital, and CLABSI incidence was compared within the experimental group over time.

Data Analysis

Data were analyzed using IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA). Participant characteristics were analyzed using frequencies, percentages, means, and standard deviations. The normality of pretest scores was assessed using the Shapiro–Wilk test, and all variables met the normality assumption. Homogeneity between the experimental and control groups was verified using the Chi-square test and independent *t*-test. Program effects were analyzed using independent *t*-tests and two-sample z-tests. In addition to statistical significance testing, effect sizes were calculated using Cohen's d to determine the magnitude and practical significance of the program's effects.

Results

General Characteristics of the Participants and Homogeneity Testing

A total of 46 nurses participated in the study, with 25 and 21 in the experimental and control groups, respectively. The participants' average age was 26.17 and 24.57 years in the experimental and control groups, respectively, indicating that those in the experimental group were slightly older. The average clinical experience was 3.39 years in the experimental group and 3.04 years in the control group.

The average number of patients cared for per day was 10.52 in the experimental group and 8.10 in the control group. The average number of patients with CVCs under their care was 6.68 in the experimental group and 6.62 in the control group. The general characteristics of the experimental and control groups were comparable (Table 2).

Table 2 Homogeneity Test of the General Characteristics and the Study Variables (N=46)

Variables	Categories	Exp.(n=25)	Cont.(n=21)	X^2 or t	*p*
		n (%) Mean±SD	n (%) Mean±SD		
Gender	Male	2 (4.3)	1 (2.2)	0.20	0.567†
	Female	23 (50.0)	20 (43.5)		
Age (year)		26.17±42.77	24.57±2.44	2.03	0.323
Education status	Bachelor's degree	22 (47.8)	19 (41.3)	1.89	0.389†
	Master's degree	3 (6.5)	2 (4.4)		
Total clinical career (year)		3.39±2.80	3.04±2.08	2.45	0.051
Total career in hematology- oncology wards (year)		1.64±1.47	1.31±1.34	0.80	0.428
Average number of patients in charge		10.52±1.47	8.10±1.14	6.08	0.115
Average number of patients with CVC in charge		6.68±2.85	6.62±1.39	0.09	0.925
Experience of CVC management education	Yes	14 (30.4)	17 (37.0)	3.23	0.072
	No	11 (23.9)	4 (8.70)		

Note: †Fisher`s exact test.
Abbreviation: Exp, experimental group; Cont, control group; CVC, central venous catheter.

Homogeneity Test of Dependent Variables Between Groups

A homogeneity test was conducted on the preintervention scores of the experimental and control groups for CVC management knowledge, management performance, hub management knowledge, hub management performance, and empowerment. The results showed no significant intergroup differences, confirming that the two groups were homogeneous with respect to the dependent variables (Table 3).

Effectiveness of the CVC Management Education Program

To evaluate the effectiveness of the CVC management education program on nurses' knowledge, performance, and empowerment in hematology-oncology wards, outcomes were assessed before and after the intervention (Table 4).

After the intervention, the experimental group demonstrated significantly higher scores than the control group in multiple domains. Specifically, CVC management knowledge increased from 13.08 ± 1.96 to 17.36 ± 1.04 in the experimental group and from 12.62 ± 2.42 to 14.09 ± 2.14 in the control group (t = 3.42, p =0.001). CVC management performance increased from 56.80 ± 7.12 to 71.72 ± 3.65 in the experimental group and from 58.29 ± 7.13 to 61.05 ± 8.51 in the control group (t = 4.37, p <0.001). Hub management performance also improved more in the experimental

Table 3 Homogeneity Test of Dependent Variables on Pretest (N=46)

Variable	Exp.(n=25)	Cont.(n=21)	t	*p*
	Mean±SD	Mean±SD		
CVC Management Knowledge	13.08±1.96	12.62±2.42	0.72	0.478
CVC Management Performance	56.80±7.12	58.29±7.13	−0.608	0.543
CVC Hub Management Knowledge	11.92±1.55	12.00±1.38	−0.080	0.936
CVC Hub Management Performance	60.12±6.42	62.09±5.54	−1.12	0.259
Empowerment	43.00±5.77	45.81±8.16	−0.917	0.359

Abbreviations: Exp, experimental group; Cont, control group; CVC, central venous catheter.

Table 4 Comparison of Variables Between the Groups (N=46)

Variable	Classification	Pretest	Posttest	Difference	t	*p*	*Cohen's d*
		Mean±SD	Mean±SD	Mean±SD			
CVC Management Knowledge	Cont.(n=21)	12.62±2.42	14.09±2.14	1.48±3.25	3.42	0.001	2.00
	Exp.(n=25)	13.08±1.96	17.36±1.04	4.28±2.28			
CVC Management Performance	Cont.(n=21)	58.29±7.13	61.05±8.51	2.76±10.46	4.37	0.000	1.68
	Exp.(n=25)	56.80±7.12	71.72±3.65	14.92±8.39			
CVC Hub Management Knowledge	Cont.(n=21)	12.00±1.38	13.67±0.66	1.67±1.28	0.88	0.382	0.62
	Exp.(n=25)	11.92±1.55	13.96±0.20	2.04±1.54			
CVC Hub Management Performance	Cont.(n=21)	62.09±5.54	62.76±5.58	0.67±8.73	2.64	0.011	0.99
	Exp.(n=25)	60.12±6.42	67.72±4.50	7.60±8.97			
Empowerment	Cont.(n=21)	45.81±8.16	43.67±7.89	-2.14±10.65	3.40	0.001	0.87
	Exp.(n=25)	43.00±5.77	49.80±6.32	6.80±7.08			

Abbreviations: Exp, experimental group; Cont, control group; CVC, central venous catheter.

Table 5 Incidence of Central Line-Associated Bloodstream Infections

Variables	Pre-Intervention	Post-Intervention	z(*p*)	*Cohen's d*
Number of CLABSI	6	6	0.22 (0.827)	0.24
Incidence of CLABSI*(1000 central line-days)	3.41	3.87		

Note: *Number of CLABSI/central line days X 1000.
Abbreviation: CLABSI, central line-associated bloodstream infection.

group (60.12 ± 6.42 to 67.72 ± 4.50) than in the control group (62.09 ± 5.54 to 62.76 ± 5.58) (t = 2.64, p =0.011). Similarly, empowerment increased significantly in the experimental group (43.00 ± 5.77 to 49.80 ± 6.32), while it decreased slightly in the control group (45.81 ± 8.16 to 43.67 ± 7.89) (t = 3.40, p =0.001).

In contrast, no significant between-group difference was found in hub management knowledge (t = 0.88, p =0.382). For the incidence of CLABSIs (Table 5), only the experimental group's medical records were analyzed, and a within-group comparison was performed. Although the incidence rate increased slightly from 3.41 to 3.87 per 1000 central line-days, this change was not statistically significant (z = 0.22, p =0.827).

Discussion

We aimed to develop a CVC management education program based on the ADDIE model, apply it to nurses in a hematology-oncology ward, and verify its effectiveness. The developed educational program included CVC management procedures, infection control, and hub management at each stage, aimed at improving nurses' performance in managing CVCs and hubs, thereby contributing to a reduction in CLABSI.

In the experimental group, the score for knowledge of CVC management increased from 13.08 to 17.36 out of a total of 18 points after the program, and showed a significant difference, compared with the control group. This result aligns with a previous research verifying the effect of CVC infection control education on neonatal intensive care unit (NICU) nurses.[12] This increase in knowledge is attributed to the systematic and specific content covering CVC insertion, maintenance, and removal, as well as infection control for each stage. Moreover, the application of diverse teaching methods, such as lecture-based sessions using PowerPoint presentations, video-based education, and practical training positively influences knowledge enhancement. This finding corresponds to that of Lee and Eun,[27] who reported increased

knowledge following a combined video and face-to-face education program for patients with allergic rhinitis. Compared with traditional lectures, video-based education reportedly enhances learners' interest and comprehension and facilitates repeated learning.[28] Therefore, the incorporation of video-based and flipped learning strategies should be encouraged in future educational programs for nurses and nursing students.

Meanwhile, the pre-intervention scores for knowledge of CVC management of the hematology-oncology ward nurses were relatively low (13.08 in the experimental group and 12.62 in the control group, out of a total score of 18). These results are similar to those from Kim's study,[29] which analyzed the knowledge of CVC management among intensive care unit nurses and reported an average score of 13.7. This suggests that low scores may be related to limited clinical experience and lack of prior education. In this study, most participants had <2 years of work experience in hematology-oncology wards, and only 30.4% and 37% of the experimental and control groups, respectively, had received prior CVC-related education. Kim[29] found that greater clinical and educational experience was correlated with higher knowledge levels. Hence, it is necessary to expand customized education programs for less experienced nurses and increase opportunities for academic activities, such as conference participation.

The CVC management performance scores in the experimental group significantly increased, from 56.80 to 71.72 out of 75 points, after the education program. This finding is consistent with prior studies[12] that reported improved CVC management knowledge and performance among NICU nurses following infection control education. The increase in performance is believed to have resulted from a combination of lectures and video-based and practical education strategies. Video-based education enables repeated practice, thereby enhancing technical skills and confidence.[26] Practical training with demonstrations and individualized feedback has been reported to improve accuracy and self-confidence in task performance.[29] These findings support the use of videos and hands-on practices as effective educational strategies that should be more widely applied in future program development. Increased knowledge following an educational program also plays a key role in improving management performance. Knowledge is a strong predictor of performance, as supported by Ha et al[14] and Kim[30] who found that greater knowledge of infection control and CVC management correlated with better practices. Therefore, educational programs should provide detailed information and training on CVC insertion, maintenance, removal, and infection control to enhance performance.

However, there was no significant improvement in hub management knowledge in the experimental group after the education program. This is in contrast to the results of Oh's study,[21] which found significant improvements following hub-focused interventions in pediatric wards. The program in the present study addressed overall CVC management, including hub care, whereas Oh's study[21] focused exclusively on hub care, potentially resulting in a greater increase in knowledge in this aspect. This finding suggests a need to strengthen hub-management content within educational programs. Future studies should consider developing a more focused curriculum on hub care.

Despite no significant increase in hub management knowledge, the hub management performance of the experimental group improved significantly, from 60.12 to 67.72. This result is consistent with Oh's study[21] and is attributed to the inclusion of theoretical and practical training specific to hub care, including demonstrations, individual practice, and 1:1 feedback. Hands-on practice using videos and demonstrations enhance procedural skills and accuracy.[26,30] The lack of a significant increase in knowledge scores may be due to participants' prior familiarity with CVC care concepts, as most nurses in hematology–oncology wards already had extensive experience managing central lines. In contrast, the significant improvement in hub management performance suggests that practical, repetitive training is more effective than theoretical instruction in reinforcing precise techniques required for infection prevention. Similar findings have been reported in previous studies, where simulation-based or practice-focused training produced greater improvements in clinical performance than in knowledge levels.[26,30]

Empowerment levels increased significantly after the program. Empowerment motivates and fosters a sense of achievement among organizational members by granting them decision-making authority and competence, thereby guiding both individuals and the organization in a positive direction.[31] Previous studies analyzing nurses' performance in infection control have shown that empowerment enhances the level of infection control practices.[32] Similarly, in this study, the improvement in empowerment had a positive effect on the CVC management performance of nurses in hematology-oncology wards. Moreover, prior research has identified knowledge as a key factor influencing empowerment,[31] indicating that higher levels of knowledge are associated with greater empowerment and improved

technical performance.[31] In the present study, participation in the educational program enabled nurses to acquire knowledge and technical skills related to CVC and hub management, which enhanced their empowerment and, consequently, improved their CVC management performance. Therefore, implementing strategies that concurrently strengthen both knowledge and empowerment is essential to further improve nurses' performance in CVC management.

However, no statistically significant reduction in the incidence of CLABSI was observed following the implementation of the education program. This finding differs from that of Oh's study[21], which reported a significant reduction in infection rates after a hub care intervention conducted in pediatric wards. One plausible explanation for this discrepancy is the distinct clinical characteristics of patients in hematology–oncology wards. Patients with hematologic malignancies are known to be at particularly high risk for catheter-related infections due to disease-related immunosuppression and treatment-related factors, including intensive chemotherapy, radiotherapy, prolonged neutropenia, and hematopoietic stem cell transplantation.[33,34] Previous studies have reported that CLABSI or catheter-related bloodstream infection rates among patients with hematologic malignancies are substantially higher than those observed in general medical or surgical populations, with reported incidence rates ranging from approximately 2.9 to 14.4 per 1000 catheter-days, and even higher rates in severely immunocompromised or neutropenic patients.[35] In such high-risk populations, the baseline incidence of infection may be sufficiently elevated to attenuate the measurable impact of a short-term, nurse-focused educational intervention on CLABSI outcomes.

In addition, in hematology–oncology wards, central venous catheters are frequently accessed not only by nurses but also by multiple healthcare professionals, including interns and residents, for procedures such as blood sampling, medication administration, and transfusion-related care. Because adherence to optimal hub management practices depends on the collective behavior of a multidisciplinary care team, an education program targeting nurses alone may be insufficient to achieve a meaningful reduction in CLABSI rates. These findings suggest that future interventions should incorporate multidisciplinary education strategies and longer follow-up periods to more accurately evaluate changes in infection-related outcomes.

Furthermore, the asymmetry in outcome measurement should be acknowledged, as CLABSI surveillance was conducted only in the intervention wards. This design limitation resulted from institutional infection surveillance policies that restricted access to CLABSI data in the control wards, making direct comparison of infection rates between groups unfeasible. Although this limitation may have weakened the internal validity related to this outcome, the inclusion of infection monitoring in the intervention wards still provided valuable insights into real-world infection patterns following educational interventions.

Therefore, future interventions should include all healthcare personnel involved in CVC care and ensure symmetrical infection surveillance across both intervention and control wards. Developing standardized, role-specific education programs and applying consistent monitoring systems would help achieve more accurate evaluations and meaningful reductions in infection rates.

Limitations

This study has several limitations. Although the statistical methods were appropriate and demonstrated sufficient power, the relatively small sample size limits the robustness and generalizability of the findings. The sample size was determined a priori using G*Power with $\alpha = 0.05$ and power = 0.80; however, a larger sample would allow more stable estimates and stronger external validity. Because randomization was not feasible, participants were assigned to groups according to their workplace hospitals. This non-randomized design may have introduced selection bias and reduced internal validity. Nevertheless, efforts were made to minimize baseline differences between groups. Future studies should recruit larger samples and apply randomized controlled or multicenter designs to enhance both internal and external validity.

Most performance outcomes were self-reported, which may have led to response bias and overestimation of intervention effects. In addition, the reliability of the CVC management performance assessment tool used in this study was moderate (Cronbach's $\alpha = 0.69$), representing a borderline value. The reliability of the CVC hub management knowledge instrument, assessed using the KR-20, also showed a borderline value (Cronbach's $\alpha = 0.69$). Although these levels of reliability are generally acceptable for newly developed or context-specific instruments, they may have

influenced the stability of the performance and knowledge measurements. Future research should include both objective and observational performance assessments and further refine the evaluation instruments to improve reliability and ensure more accurate measurement of intervention effects over time.

Another limitation of this study is that the infection outcome was evaluated using CLABSI rates, which represent an epidemiological surveillance measure rather than a clinically confirmed diagnosis such as Catheter-related bloodstream infection (CRBSI). Although CLABSI is widely used for infection monitoring in hospital settings, it may not accurately reflect the true clinical incidence of catheter-related bloodstream infections. Therefore, future studies should consider including both epidemiologic (CLABSI) and clinical (CRBSI) indicators to provide a more comprehensive assessment of infection outcomes.

A potential limitation of this study is that the literature review primarily focused on studies conducted in Korea. Although this approach allowed for an in-depth understanding of the local clinical and educational context, it may limit the generalizability of the findings to other healthcare settings with different policies, resources, and infection control practices. To address this limitation, future studies should incorporate international literature and cross-cultural comparisons to validate the applicability of the developed program and to identify globally relevant components of CVC management education.

Conclusion

This study developed a CVC management education program based on the ADDIE model and applied it to nurses working in hematology-oncology wards to evaluate its effectiveness. The program comprised six sessions addressing comprehensive catheter care, including insertion, maintenance, removal, hub management, and infection control.

After implementation, the experimental group showed significantly higher scores in knowledge and performance of CVC and hub management, as well as empowerment, compared with the control group. However, the program alone did not lead to a significant reduction in CLABSI rates. This finding underscores that improvements in infection outcomes cannot be achieved by nurse education alone. CLABSI prevention requires coordinated efforts among multiple healthcare professionals involved in catheter insertion, maintenance, and infection control. Therefore, future research should adopt a multidisciplinary approach by including physicians, infection control practitioners, and other healthcare staff in educational and quality improvement initiatives. Moreover, incorporating objective or observational assessments of performance will allow more accurate evaluation of intervention effects. Conducting multicenter studies across diverse clinical settings would further strengthen the evidence base and enhance the generalizability of the findings.

Abbreviations

CVC, central venous catheter; CLABSI, central line-associated bloodstream infection; KDCA, Korea Disease Control and Prevention Agency; ADDIE, Analysis, Design, Development, Implementation, Evaluation; KR-20, Kuder–Richardson formula 20; KONIS, Korean Nosocomial Infections Surveillance System; CRBSI, catheter-related bloodstream infections; NICU, neonatal intensive care unit; TIVAD, totally implantable venous access device.

Ethics Approval and Informed Consent

This study was approved by the Institutional Review Board of the Eulji University Hospital in Daejeon City (approval no. EMC202307005001-HE004). Written informed consent was obtained from all participants prior to data collection.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

There is no funding to report.

Disclosure

The author(s) report no conflicts of interest in this work.

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