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Education Programs for Invasive Procedures Involving Nurses: A Scoping Review

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Abstract

Background: Implementing invasive procedures is an important part of patient management by clinical nurses; however, there are gaps between nurses' actual knowledge and skills and expected professional care capacity. **Purpose:** This scoping review aimed to map the existing literature related to recent institution-provided educational programs for invasive procedures involving clinical nurses. This study seeks to understand the contents of educational programs and the methods for assessing educational effects. **Methods:** This scoping review was completed using the following four databases: PubMed (MEDLINE), Embase, Cochrane Library, and Emcare for the period 2000-2022. We included studies that used all forms of educational approaches (e.g., didactic lectures, hands-on training, or on-the-job training). This scoping review considered peer-reviewed publications published in English using quantitative, qualitative, or mixed approaches. A total of 83 studies underwent in the final analysis. **Results and Conclusion:** A combination of didactic lectures and hands-on training was provided as an educational program in most studies. Contrary to our prediction, educational interventions with advanced technologies such as VR are extremely rare, suggesting that the effectiveness of advanced technologies in learning invasive procedures should be examined to facilitate and retain educational effects more efficiently in future studies. Regarding the assessment of educational effects, nurses' cognitive (*i.e.*, theoretical knowledge about procedures), psychomotor (*i.e.*, implementing procedures), and psychological aspects (e.g., confidence and self-efficacy in procedures) were evaluated using questionnaires and observational methods. While most studies used a one-group pretest-posttest design, the ratio of randomized controlled trials (RCT) was relatively low. Thus, an RCT design should be introduced in future studies to test the validity of the developed educational program more accurately.

Keywords

Training, Education, Invasive Procedure, Nurses, Assessment

1. Introduction

Invasive procedures such as endotracheal suctioning and peripheral venous catheterization are an important part of nursing care for many patients; however, any invasive procedure performed incorrectly by nurses has the potential to expose patients to serious physical harm. The World Health Organization defines patient safety as the elimination of unnecessary harm to patients and a constant decrease in hazards [1]. High-quality nursing care and avoidance of nursing errors depend on nurses' adherence to patient safety standards [2].

Nursing students have fewer opportunities to implement invasive procedures on their patients. Students learn how to conduct invasive procedures using patient simulators and controlled environments in simulation laboratories. Simulation education in schools provides immersive and hands-on learning experiences. Nevertheless, it is difficult for nursing students to acquire complete knowledge and skills in invasive procedures via simulation education alone [3] because of barriers to the use of high-fidelity patient simulators [4]. Despite fewer opportunities for invasive procedures in schools, clinical nurses must conduct invasive treatments accurately from the start of their careers.

There is a substantial gap between actual and expected professional patient care capacity for invasive procedures, particularly among inexperienced nurses [5]. Previous research found discrepancies between guidelines and invasive procedures among nurses [6]. For example, the American Association for Respiratory Care developed guidelines to reduce suction-related adverse effects [7]. A multicenter observational research in France found that nurses did not follow recommendations for suctioning maneuvers (e.g., proper suction catheter size) [6]. Similarly, a cross-sectional study discovered that many critical care nurses do not follow endotracheal suctioning guidelines [8]. According to questionnaire research, many nurses were ignorant of the suggested method of tracheal suctioning [9]. A previous study found that nurses had poor understanding of the guidelines for preventing catheter-related bloodstream infections [10]. A cross-sectional survey was conducted to evaluate the association between adherence to clinical practice guidelines for peripheral venous catheters and work settings (leadership, feedback processes, and organizational characteristics). These findings indicate the need for various strategies to improve nurses [11]. In Japan, the

Ministry of Health, Labour, and Welfare (MHLW) developed training guidelines for new nurses and established knowledge, skills, and attitude goals for new nurses [12]. While the MHLW guidelines state that being able to perform invasive procedures (e.g., suctioning) within one year of starting a job is the attainment goal, it has been reported that the achievement levels of invasive procedures are relatively low and that many novice nurses find it difficult to implement invasive procedures [13]. This result indicates that on-the-job training alone may not be sufficient for acquiring invasive techniques. Given the disparities between guidelines (or attainment goals) and practice, it is critical that clinical nurses continue to receive appropriate and effective education programs to build and brush up their knowledge and skills regarding invasive procedures, which will likely result in improved patient outcomes. Many hospitals and other institutions emphasize the importance of continuous education programs to facilitate nurses' learning activities using various methods and tools to improve their clinical performance. However, it remains unclear how clinical nurses learn and update their knowledge and skills regarding invasive procedures in hospitals and institutions. Therefore, the purpose of this scoping review was to evaluate and map the extant literature relevant to clinical nurse education programs on invasive procedures. There is yet to be a published or registered scoping review or systematic review on this topic.

As technology evolves, educational programs for learning about invasive treatments also evolve. For example, low- and high-fidelity patient simulators are used as teaching tools in nursing education. Numerous studies have demonstrated the efficacy of patient simulations in nursing education [14] [15] [16] [17]. Recently, virtual reality (VR) technology has been offered as a viable educational tool in nursing education [18] [19] [20]. Some studies have created VR systems that enable nurses to perform invasive procedures [21] [22] [23]. For example, the use of VR in nursing student training on intravenous catheterization has been found to be a successful teaching tool [23]. An interventional study revealed that virtual reality (VR) instruction materials with first-person videos improved tracheal suction learning [22]. To perform urinary catheterization, a computer graphic-based VR system with haptic feedback was created [24]. A VR mechanical ventilation nursing program was recently developed [21]. Here, it is predicted that educational approaches with advanced technologies such as VR and augmented reality (AR) will accelerate following the spread of COVID-19 because nursing students have limited clinical practice. Given the remarkable advances in methods for acquiring and improving the knowledge or skills of invasive procedures in nursing schools, it is hypothesized that clinical nurse education programs provided by hospitals and institutions will also change.

This scoping review aimed to provide answers to the following research questions:

- How are clinical nurses educated in hospitals and other institutions to obtain the theoretical knowledge and skills concerning invasive procedures?
- How is the effectiveness of the education programs of the invasive procedure

assessed?

In summary, the past researches have shown the significance of continuous education programs for clinical nurses, as nurses' clinical competence with invasive procedures are insufficient. The research goal of this scoping review is to present vital findings regarding education programs for invasive procedures involving clinical nurses.

2. Methods

2.1. Eligibility Criteria and Search Strategy

We chose the inclusion criteria for the scoping review based on the population concept context mnemonic proposed by the Joanna Briggs Institute [25] [26]. The study population consisted of clinical nurses, independent of employment duration or age. We also included studies in which both clinical nurses and other personnel (e.g., co-medicals and physicians) participated. However, because we were interested in educational programs provided in hospitals or institutions, studies involving nursing students were excluded from this scoping review. This concept refers to educational programs in which clinical nurses learn about various invasive procedures involving nurses. We included studies that used all forms of educational approaches (e.g., didactic lectures, hands-on training with patient simulators, or on-the-job training). This scoping review included studies on clinical nurses in a variety of settings. Hospitals, clinics, nursing homes, and nursing facilities were defined as contexts. This scoping review considered peer-reviewed publications published in English using quantitative, qualitative, or mixed approaches. Because we focused on the latest educational programs, we searched for articles published since the year 2000. Research librarians/information scientists assisted in defining search strategies and identifying relevant databases in this scoping review, because each database has a unique search approach. We searched four electronic bibliographic databases: PubMed (MEDLINE), Embase, the Cochrane Library, and Emcare. **Appendix Table S1** shows the details of the PubMed search approach. The article search date was January 6, 2023.

2.2. Screening and Analysis

A total of 5393 articles were retrieved from these four databases. Using End Note X9, we removed duplicate studies (n = 132) and imported the remaining studies (n = 5261) into Rayyan, a web application for screening [27]. **Figure 1** shows the scoping review process according to the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) flow diagram [28]. Three reviewers independently screened the article titles and abstracts for potential compliance with the inclusion criteria (first screening). Furthermore, the full texts of the potentially included studies were independently screened by three reviewers (second screening). Any conflicts were resolved with the assistance of another reviewer. A total of 5261 titles and abstracts were screened, of which 5049

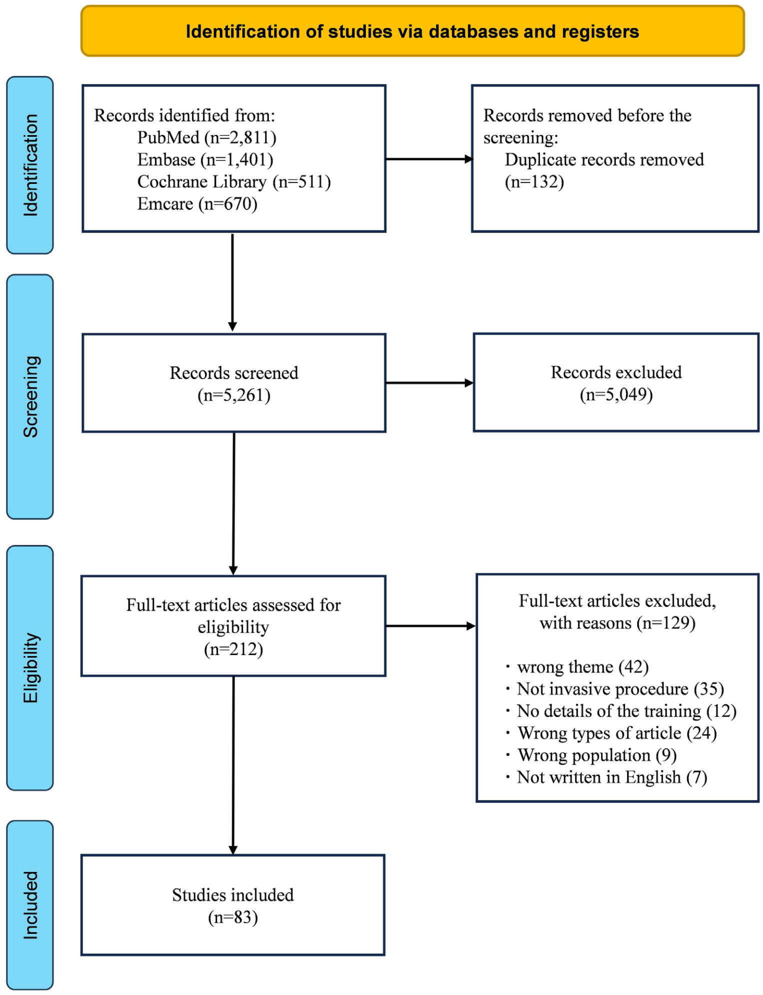

Figure 1. PRISMA flow diagram for the scoping review process.

studies were excluded because they did not meet the inclusion criteria. The remaining 212 studies underwent a full-text review (*i.e.*, a second screening), and 129 studies were excluded for several reasons (see Figure 1). A total of 83 studies were included in the final review. One reviewer charted the extracted data into a data charting table for detailed analysis. Subsequently, these studies were classified according to their characteristics (e.g., contents of the education program and assessment methods) and are summarized in the tables. Finally, we describe the characteristics of this study based on the results of these analyses.

3. Results

3.1. Characteristics of Included Studies

Table 1 summarizes the characteristics of the studies included in the final review. According to the year of publication, the number of studies was classified as follows: two studies (2.4%) from 2001 to 2005 (5 years), six studies (7.2%) from 2006 to 2010 (5 years), 16 studies (19.3%) from 2011 to 2015 (5 years), 32 studies (38.6%) from 2016 to 2020 (5 years), and 27 studies (32.5%) from 2021 to

Table 1. Study characteristics.

Author/Year	Country/Area	Design	Procedure	Program	Assessment	Ref.
Day *et al.*, 2001	UK	a	b	Didactic and interactive approaches/Practical bedside demonstration	Knowledge-based questionnaire/ Non-participant observation	[29]
Chang *et al.*, 2002	China	a	a	Lecture/Skill learning	Checklist to assess/State-trait anxiety inventory/ Semi-structured interview	[30]
Ozyazicioğlu & Arikan, 2008	Türkiye	b	a	Lecture session/Question & answer session/ Booklets	Observation form	[31]
Tsai *et al.*, 2008	Taiwan Area	a	a	Virtual reality simulation system	Knowledge test/Satisfaction assessment of the training	[32]
Day *et al.*, 2009	UK	a	b	Performance feedback (Simulation & Clinical setting)	Knowledge test/Observation	[33]
Anson *et al.*, 2010	US	b	a	Web-based online tutorial program	Self-assessment of knowledge, attitudes and practice	[34]
Banks *et al.*, 2010	US	b	a	Multifaceted educational program (Self-study module/ Skills laboratory/Journal club)	Knowledge test/Confidence assessment/Educational modality	[35]
Avelar *et al.*, 2010	Brazil	c	a	Theoretical session/Practice session	Knowledge/Skills/Ability to identify arteries/Positioning of catheters	[36]
Wilfong *et al.*, 2011	US	a	a	Simulation training	Number of tries the nurse needed to successfully insert an intravenous	[37]
Chee *et al.*, 2011	Australia	c	a	Theoretical session/Practical demonstration and practice session using simulation arms	Success rates of cannulations/ Participants' assessment of the training program	[38]
Schneider, 2012	UK	b	c	Educational posters/Lectures with handouts	Knowledge test/Number of bladder infections	[39]
Lyons *et al.*, 2012	US	b	a	Didactic instruction session/ Practice session using a computer simulation haptic device and mannequins	Knowledge test/ Skill test/ Confidence levels	[40]
Altun, 2012	Türkiye	b	a	Interactive lecture-based workshop	Knowledge test using a questionnaire	[41]
Moore, 2013	US	c	a	Didactic and hands-on course/ 1-on-1 individualized instruction with a nurse champion	Success rate of Ultrasound-guided peripheral intravenous line	[42]
Hadian & Sabet, 2013	Iran	b	b	Lecture/ Films/ Demonstration	Skill checklist/ Premature infant pain profile	[43]
Dorton *et al.*, 2014	US	b	b	Online self-paced lecture/ Simulation laboratory session with the patient simulator	Comfort level/ Knowledge test	[44]
Blackman *et al.*, 2014	Australia	b	a	E-learning	Questionnaire relating to knowledge and skill	[45]
Craft *et al.*, 2014	US	c	a	Simulation-based training with a mannequin simulator	Performance checklist	[46]

Continued

Ault *et al.*, 2015	US	c	a	1:1 mentoring sessions including didactic session/ Hands-on training session/ Live patients	Number of successful intravenous placements/ Time taken for successful vessel cannulation	[47]
Stephenson *et al.*, 2015	US	c	b	Web-based didactic approach/ Simulation	Knowledge test/ Skill checklist/ Lasater clinical judgment rubric	[48]
Maeda *et al.*, 2015	Japan	c	c	Didactic lecture	Questionnaires to measure satisfaction, learning achievement, and usefulness	[49]
Schade *et al.*, 2015	US	b	a	Didactic session/ Hands-on session	Knowledge test/ Observational evaluation/ Assessment of psycho-motor domain	[50]
Adhikari *et al.*, 2015	US	c	a	Didactic lecture session/ Practical session	Confidence and comfort level/ Direct observation	[51]
Kaur *et al.*, 2015	India	a	b	Not described in detail	Knowledge and skill scores	[52]
Oliveira & Lawrence, 2016	US	c	a	Didactic session/ Hands-on session	Success rates, number of attempts, and complications after training	[53]
Kuszajewski *et al.*, 2016	US	b	b	Practice using a mannequin and simulation scenario/ Intubation of live patients under the supervision	Knowledge test/ Endotracheal intubation checklist/ Self-confidence survey	[54]
Crous & Armstrong, 2016	South Africa	b	a	Watching a video/ Group discussion	Observational checklists	[55]
Keleekai *et al.*, 2016	US	a	a	Self-paced online education/ Simulation-based live training	Knowledge assessment/ Confidence assessment/ Skill checklist	[56]
Meska *et al.*, 2016	Brazil	b	c	Theoretical session/ Practice session using a low-fidelity simulator	Self-confidence scale	[57]
Vinayaka & Bernet, 2016	India	b	b	Not described in detail	Knowledge test/ Observational checklist	[58]
Jayalaxmi *et al.*, 2016	India	b	a	Structured teaching program using demonstration on mannequin, charts and slides	Knowledge test/ Observational checklist	[59]
Harjot *et al.*, 2016	India	b	b	Not described in detail	Knowledge test/ Observational checklist	[60]
Gosselin *et al.*, 2016	Canada	b	a	Theory session/ Practice lab session	Cost of inserting the ultrasound-guided peripheral venous access	[61]
Glover *et al.*, 2017	US	c	a	Self-paced interactive e-learning instruction/ Simulation-based practice	Skills Checklist/ Knowledge test	[62]
Gopalasingam *et al.*, 2017	Denmark	b	a	E-learning course/ Practice using gelatin phantoms/ Supervised catheterizations	Number of catheters used/ Success rate of catheters placements	[63]
Morgaonkar *et al.*, 2017	India	b	a	Interactive lecture for knowledge/ Hands-on training on manikins for skills	Skill checklist/ Knowledge test	[64]

Continued

Ramsey *et al.*, 2018	US	b	b	Lecture/ Simulation	Comfort level/ Knowledge test	[65]
Feinsmith *et al.*, 2018	US	b	a	Didactic course/ Hands-on course using a vascular-access model	Numbers and rates of successful attempts	[66]
Adams *et al.*, 2018	US	b	d	Didactic session/ Hands-on training with abscess model	Confidence level/ Assessment of the educational utility	[67]
Garner *et al.*, 2018	US	b	a	Oral instruction/ Simulation using a low-fidelity equipment	Knowledge test/ Skills checklist	[68]
Han *et al.*, 2018	Korea	b	b	Lecture/ Simulation	Self-efficacy assessment/ Clinical performance assessment	[69]
Leeper *et al.*, 2018	US	b	b	Didactic lectures/ Hands-on skills training/ High-fidelity simulations	Course evaluation assessment/ Knowledge assessment	[70]
Lengetti *et al.*, 2018	US	a	c	Self-paced learning modules/ Individualized feedback and correctives from an expert nurse	Skill checklist/ Self-regulation assessment	[71]
Ostrowski *et al.*, 2019	US	c	a	Didactic module (slide and videos)/ Simulation session	The time required for catheter insertion/ CRNA's evaluation	[72]
Covington *et al.*, 2019	US	b	b	Online educational module/ Simulation using low-fidelity mannequins	Knowledge test/ Self-efficacy assessment	[73]
Short *et al.*, 2019	US	b	b	Lecture/ Hands-on skills	Confidence level for knowledge and skill	[74]
Bortman *et al.*, 2019	US	b	a	Online self-paced didactic component/ Integrated proctored hands-on workshops	Course assessment/ Knowledge test	[75]
Garcia-Gasalla et al, 2019	Spain	b	a	Peripheral venous catheter infection prevention bundle	Rates of peripheral venous catheter-associated bloodstream infection	[76]
Laghezza *et al.*, 2019	US	b	b	Instruction sessions/ Demonstration/ Practice on simulators	Online-knowledge test/ Skill tests	[77]
Askey & Clements, 2019	Australia	c	a	Education component/ Practical component	Insertion success rate/ Correct line tip positioning	[78]
Stuckey & Curtis, 2019	US	c	a	Didactic session/ Hands-on session	Success rate for the catheter attempts	[79]
Lakhkar & Damake, 2019	India	b	a	Not described in detail	Numbers of the intravenous insertions/ Complications	[80]
Galen *et al.*, 2020	US	b	a	Instructional video/ Practice using a mannequin	Number of the catheters/ Success rates of the catheters	[81]
Kadhim & Mhabes, 2020	Iraq	b	b	Education program (e.g. guided group discussion and role playing)/ Practices	Observational checklist	[82]
Elsobkey *et al.*, 2020	Egypt	b	a	Knowledge session/ Performance session	Knowledge test/ Number, duration and success rate of the attempts/ Pain rating scale	[83]
Azizian *et al.*, 2020	Iran	c	b	Education video/ Immediate feedback provided by the researcher	Checklist for assessing nurses' endotracheal suctioning practices	[84]
Kadhim & Mhabes, 2021	Iraq	b	b	Lectures/ Practices	Knowledge test	[85]

Continued

Hassanein *et al.*, 2021	Egypt	b	a	Theoretical session/ Structured simulation-based learning session	Knowledge test/ Attitude rating scale/ Observational skill-checklist	[86]
Huang *et al.*, 2021	Taiwan Area	a	a	Mobile phone application with video clips	Knowledge test/ Observation of procedural skills	[87]
Balachander *et al.*, 2021	India	b	a	Simulation with a newborn mannequin	Checklist score sheet/ Blood stream infection rate	[88]
Niyyar, 2021	US	b	a	Didactic session/ Hands-on simulation	Questionnaire for assessing procedural comfort and competency	[89]
Russell *et al.*, 2021	US	b	a	Didactic lecture/ Hands-on practice session	Confidence assessment/ frequency tracker/ Intravenous access score/ Number of peripheral catheters	[90]
Filipovich *et al.*, 2021	US	b	a	Didactic session/ Hands-on skills training	Knowledge test/ Confidence assessment	[91]
Divya *et al.*, 2021	India	b	a	Lectures/ Practice demonstration	Knowledge test/ Observational checklist	[92]
Hackett *et al.*, 2021	US	b	a	Didactic learning/ Simulation training/ Insertion validation.	Success rates of first-time insertions	[93]
Steinbauer *et al.*, 2021	Austria	b	b	Lectures/ Simulation Training	Questionnaires	[94]
Amick *et al.*, 2022	US	b	a	Instructional video/ Didactic lecture/ Hands-on practice using a simulator	Skill checklist/ Confidence assessment/ Numbers of successful catheter insertions	[95]
McKinney *et al.*, 2022	US	b	a	Didactic lecture/ Simulation	Confidence level/ Knowledge test/ Proficiency test	[96]
Scimò *et al.*, 2022	France	c	a	Theoretical training/ Observation/ Supervised and unsupervised insertions	Patient pain using a VAS/ Amount of PICC inserted/ Insertion time	[97]
Anderson *et al.*, 2022	US	c	a	Didactic session/ Hands-on session	Success rate of the catheter placement/ Comfort and confidence assessment	[98]
Amick *et al.*, 2022	US	c	a	Instructional video/ Recorded lecture/ Practice on simulator/ Supervised insertions on patients	Checklist for skills/ Numbers of ultrasound-guided peripheral intravenous catheter insertion	[99]
Bhargava *et al.*, 2022	US	b	a	Presentation on ultrasound basics/ Hands-on practice with a vessel simulator	Stick success rate of peripheral intravenous placement	[100]
van Loon *et al.*, 2022	Netherlands	c	a	Theoretical training/ Hands-on training/ Supervised life-case training	Knowledge test/ Successful attempts/ Number of successful cannulations and the time taken to perform them	[101]
Mousavi *et al.*, 2022	Iran	c	a	Messages on PIVC placement sent by short message service	Knowledge test/ Observational skill assessment	[102]
Nonas *et al.*, 2022	US	b	b	Didactic session/ Hands-on practice with high-tech mannequins/ Learning in the ICU	Knowledge test/ Course assessment	[103]

Continued

Bagley, 2022	US	b	a	Online didactic module/ Hands-on training/ Skill application	Success rate of US-guided PIV insertions/ Complication rates/ Program evaluation	[104]
Shimizu *et al.*, 2022	Japan	c	a	Role playing scenarios	Text mining and natural language processing	[105]
Yusuf *et al.*, 2022	US	b	d	Online didactic lecture/ High-fidelity simulation	Skill self-assessments	[106]
Tiu *et al.*, 2022	US	b	b	Online module/ Hands-on simulation activity	Comfort level/ Knowledge test	[107]
Jacobs, 2022	US	b	a	Online learning module/ Simulation using a plastic arm	Skills checklist/ Confidence assessment/ Success rate of first attempt	[108]
Schott *et al.*, 2022	US	b	a	Video provided instruction/ Practice with a self-contained learning cart	Comfort assessment	[109]
Thompson *et al.*, 2022	US	b	b	Self-paced didactic component/ Simulation component	Numbers of endotracheal intubations/ First-attempt success rates/ Occurrence of adverse associated events	[110]
Vieira *et al.*, 2022	Brazil	c	b	Simulation workshops	Knowledge tests	[111]

Design: a. randomized controlled trial (RCT) design; b. one-group pretest-posttest design; c. others. **Procedure**: a. vascular puncture and management; b. air management; c. urinary indwelling catheter insertion and management; d. incision and drainage of skin abscesses.

2022 (2 years). More than half of the studies were conducted in the United States (n = 44; 53%), followed by India (n = 8; 9.6%), the United Kingdom (n = 3; 3.6%), Brazil (n = 3), Iran (n = 3), and Australia (n = 3). Regarding study design, 64% (n = 53) of the included studies used a one-group pretest-posttest design, followed by a randomized controlled trial (RCT) design (n = 9; 10.8%).

3.2. Classification of the Invasive Procedures Involving Nurses

The invasive procedures in the included studies were mainly classified into four categories (**Figure 2**): 1) vascular puncture and management, 2) airway management, 3) urinary indwelling catheter insertion and management and 4) incision and drainage of skin abscesses. Almost two-thirds of the studies (n = 54; 65.1%) were included in the category of vascular puncture and management (e.g., peripheral intravenous catheterization, buttonhole cannulation, phlebotomy, or port-a-cath injection). Of these studies, 28% (n = 23) were classified according to the category of airway management (e.g., endotracheal suctioning). The ratios of studies included in the categories of urinary indwelling catheter insertion and management (n = 4; 4.8%) and incision and drainage of skin abscesses (n = 2; 2.4%) were small.

3.3. Contents of the Interventional Education Programs

Table 2 presents the educational methods used for learning invasive procedures.

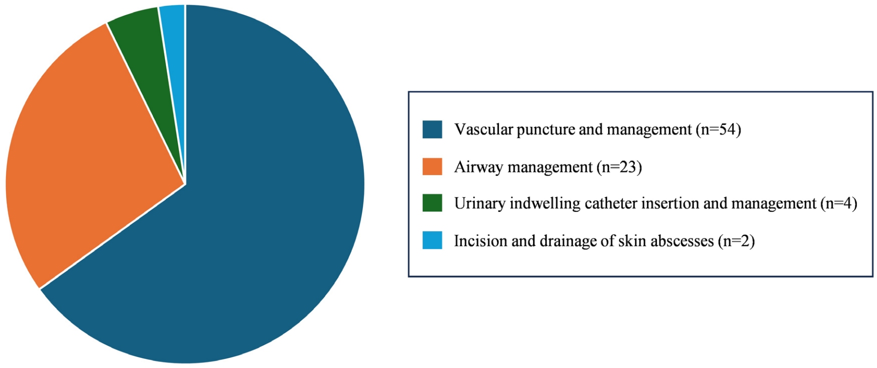

Figure 2. Classification of invasive procedures involving clinical nurses.

Table 2. Classification of education methods.

Education methods	N	%
In-person lecture and hands-on training in simulation or clinical setting	50	60.3
Online lecture (e-learning) and hands-on training in simulation or clinical setting	10	12.1
Hands-on training in simulation and clinical setting	7	8.4
In-person lecture	4	4.8
Online lecture/ E-learning	3	3.6
Virtual reality simulation training	1	1.2
Mobile phone application	1	1.2
Short message service	1	1.2
Comparison between training video and recorded video of participant's skill	1	1.2
Multi-faceted educational intervention	1	1.2
Not described in detail	4	4.8
Total	83	100

Most of the studies (n = 60; 72.4%, top two lines in **Table 2**) utilized a combination of didactic lectures and hands-on training in a simulation (*i.e.*, patient simulator) or clinical setting (*i.e.*, implementation of the procedure under supervision). Some of these combined studies (n = 10; 12.1%) provided self-paced online programs (*i.e.*, e-learning) as a lecture session. Several studies used hands-on training (n = 7) and lectures alone (in-person: n = 4; online: n = 3). A few studies have utilized advanced technologies for learning the knowledge and skills of invasive procedures: virtual reality stimulation [32], mobile phone applications [87], and short message services [102].

3.4. Evaluation Tools Investigating Educational Effects

Regarding the assessments, the plural tools (*i.e.*, two or three methods) were used in one study. As shown in **Table 3**, nurses' knowledge (and skills) was

Table 3. Classification of assessment methods. Note that plural methods were frequently used in one study.

Assessment methods	N	%
Questionnaire assessment of knowledge and skills	41	49.3
Observational assessment of skills	31	37.3
Numbers, success (or fail) rates or time of procedures/ Procedure-related complication and infection	29	35
Confidence, comfort or self-efficacy level	21	25.3
Assessment of education program	11	13.3
Self-assessment of competency	4	4.8
Pain assessment of patients	3	3.6

evaluated using questionnaires (*i.e.*, knowledge tests) in almost half of the studies (n = 41; 49.3%). In addition, the observation of skill (*i.e.*, conducting the invasive procedure) was used in 37% of the studies (n = 31), in which the evaluators assessed the participants' performance with checklists according to the guidelines. For more objective tools, 35% of the studies (n = 29) measured the success rates of the attempts or the time required to complete the procedure in a simulation or clinical setting. In one-quarter of the studies (n = 21; 25.3%), nurses' psychological aspects (*i.e.*, confidence, comfort, or self-efficacy level) to conduct the invasive procedure were recorded using questionnaires. In some studies (n= 11; 13.3%), participants directly assessed the developed educational programs themselves. Pain was also assessed in a few studies (n = 3; 3.6%) using the visual analog scale [97] or a premature infant pain profile [43].

4. Discussion

In this scoping review, we mapped the existing literature relevant to educational programs on invasive procedures involving clinical nurses. In particular, this study sought to understand the contents of educational programs and the methods for assessing educational effectiveness.

Our first research question was "How are clinical nurses educated to obtain the theoretical knowledge and skills concerning invasive procedures?" Given that professional knowledge and techniques are necessary for clinical nurses to safely administer invasive procedures to patients, it is natural that a combination of didactic lectures (*i.e.*, knowledge) and hands-on training (*i.e.*, skill) was provided most frequently. In the lecture session on the combination, some studies developed online educational materials (e.g., PowerPoint slides and video clips) to enable busy clinical nurses to acquire knowledge without being restricted by place or time. Few studies have investigated the effectiveness of online learning alone [45]. The hands-on training sessions in most studies were performed using high- or low-fidelity patient simulators in the hospital laboratory. In addition to such simulation sessions, an invasive procedure for patients was implemented under the supervision of expert nurses or physicians (*i.e.*, on-the-job training).

Despite its rarity, studies using advanced technologies have been conducted. Tsai *et al.* [32] developed a computer-assisted protocol using VR to conduct Port-a-Cath as a training program for novice nurses. Recently, Huang *et al.* [87] developed and tested a mobile phone application that included video clips for nurses regarding the use and care of central venous catheters. However, contrary to expectations, clinical studies using VR or information technology are extremely rare. Given the existing VR studies on nursing students [18]-[24], we inferred that there are some gaps between nursing students' and clinical nurses' VR studies. For instance, there might be technical and cost barriers to develop newer education materials using VR in hospitals. Our findings suggest that the effectiveness of training with more advanced technologies, such as VR and AR, in learning invasive procedures by nurses should be investigated in future studies.

The second research question was "How is the effectiveness of the education programs assessed?" Nurses' theoretical knowledge related to invasive procedures (cognitive domain) was mainly assessed using questionnaires (*i.e.*, knowledge tests). These knowledge tests were administered before and after the interventional education program (*i.e.*, pre- and post-tests), and the differences between the two were evaluated as educational effects. Because clinical nurses require competency in not only cognitive but also psychomotor skills when implementing the nursing process [112], many studies have used observational methods, in which nurses' performance of the invasive procedure was evaluated with checklists according to the guidelines. There are two types of observation methods, direct and indirect, using video-recorded images. These observations are advantageous for the step-by-step assessment of the components of the invasive procedure. The results of attempts at invasive procedures were evaluated in approximately one-third of the studies. For instance, the number of successful catheter insertions and the time required to perform them were measured. In addition, because any invasive procedure conducted incorrectly has the potential to expose patients to serious physical harm, some studies have counted the number of procedure-associated complications and infections before and after educational interventions. These measures are useful for objectively assessing the effectiveness of educational programs in clinical settings. Because novice and inexperienced nurses feel uneasy about performing invasive procedures, nurses' psychological aspects such as confidence, comfort, and self-efficacy were assessed using questionnaires in some studies. In summary, the assessments used in the included studies were largely classified into three categories: cognitive (theoretical knowledge), psychomotor aspect (*i.e.* skill), and psychological aspects regarding the invasive procedure.

Given the years of publication of the included studies, the number of studies involving educational program development for invasive procedures among nurses is increasing. In addition, the country where most research had been conducted was the United States, meaning that studies relating to the development of education programs on invasive procedures for nurses have increased in the US. This result may involve at least three aspects: working environment, care quality, and cost. For instance, in the working environment, the Accreditation Council for Graduate Medical Education in the United States limited the number of work hours for residents to 80 hours weekly in 2011. This causes task shifting in hospitals, resulting in an increasing need for clinical nurses (or nurse practitioners) to conduct invasive procedures instead of physicians. Regarding care quality, targeting nurses for training in invasive procedures in the acute care setting is advantageous because nurses have direct patient contact 24 hours a day. This may lead to an improved quality of care for patients. Regarding cost, for example, infections related to peripherally inserted central catheters represent a significant proportion of central line-associated bloodstream infections, which are involved in an US$2.68 billion excess cost each year in the United States [113]. Thus, improving the success rate of peripherally inserted central catheters would be linked to reduced medical costs.

While most study designs were one-group pre- and post-test designs (64%), the ratio of RCT designs was relatively low (10.8%). While the purpose of this scoping review was not to clarify the best ways of education, our further interest was in how to learn invasive procedures most efficiently for clinical nurses. In particular, when developing newer educational methods, a comparison between previous and newer methods (control versus experimental groups) would provide insightful findings. Therefore, an RCT design is needed to strengthen the validity of the developed educational programs in future studies, despite some barriers to the introduction of control conditions in the clinical setting.

5. Limitations

This scoping review has some limitations. First, we included only studies described in the English language. Therefore, it is possible that relevant studies published in other languages were omitted. Second, unlike systematic reviews, scoping reviews generally do not assess the overall quality of the evidence. However, they are advantageous for summarizing vital evidence. Third, while we searched broadly in four comprehensive databases, it is still possible that relevant research and their findings have been missed out. Despite these limitations, the strength of our study lies in its presentation of vital findings regarding educational programs for invasive procedures involving clinical nurses.

6. Conclusion

This scoping review mapped the existing literature relevant to educational programs on invasive procedures involving clinical nurses. In this review, we focused on the content of educational programs and evaluation methods for educational effects. We found that a combination of didactic lectures and hands-on training was frequently provided. Education with more advanced technologies was extremely rare, although there have been some VR studies for nursing students. Regarding the assessment of educational effects, nurses' cognitive, psychomotor, and psychological aspects were evaluated using questionnaires and observations. Future studies should examine the effectiveness of more advanced technologies for learning invasive procedures to facilitate and retain the educational effects more efficiently.

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Authorship Contributions

Conceptualization, H.S., A.S., M.M., N.Y., C.E., and S.S.; *Screening*, H.S., A.S., M.M., and S.S.; *Formal analysis*, H.S. and S.S.; *Data curation*, S.S.; *Writing-original draft preparation*, H.S. and S.S.; *Writing-review and editing*, A.S., M.M. and N.Y.; *Funding acquisition*, H.S. All authors have read and agreed to the published version of the manuscript. H.S and S.S. contributed equally to this work.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

Table S1. Search strategy for PubMed. The search was conducted 6 January 2023.

Query
(("Invasive procedure"[tiab] OR "Invasive procedures"[tiab] OR (("Invasive"[tiab] OR "Invasiv*"[tiab]) NOT "non-invasive"[ti]) OR "Suction"[Mesh] OR "Suction"[tiab] OR "Suctioning"[tiab] OR "Suctions"[tiab] OR "Mechanical Aspiration"[tiab] OR "tracheal suction"[tiab] OR "tracheal suctioning"[tiab] OR "Drainage"[Mesh] OR "Drainage"[tiab] OR "Paracentesis"[tiab] OR "Catheters"[Mesh] OR "Catheters"[tiab] OR "Catheter"[tiab] OR "Catheterization"[Mesh] OR "Catheterization"[tiab] OR "Catheterisation"[tiab] OR "Catheterize"[tiab] OR "Catheterise"[tiab] OR "Catheteriz*"[tiab] OR "Catheteris*"[tiab] OR "Cannulation"[tiab] OR "Cannulations"[tiab] OR "Cannulat*"[tiab] OR "peripheral venous catheters"[tiab] OR "peripheral venous catheter"[tiab] OR "peripheral venous catheter*"[tiab] OR "Respiration, Artificial"[Mesh] OR "Artificial Respiration"[tiab] OR "Mechanical Ventilation"[tiab] OR "High-Frequency Ventilation"[tiab] OR "High-Frequency Jet Ventilation"[tiab] OR "Interactive Ventilatory Support"[tiab] OR "Liquid Ventilation"[tiab] OR "Noninvasive Ventilation"[tiab] OR "One-Lung Ventilation"[tiab] OR "Positive-Pressure Respiration"[tiab] OR "Continuous Positive Airway Pressure"[tiab] OR "Intermittent Positive-Pressure Breathing"[tiab] OR "Intermittent Positive-Pressure Ventilation"[tiab] OR "Ventilator Weaning"[tiab] OR "Ventilators, Mechanical"[Mesh] OR "Mechanical Ventilator"[tiab] OR "Mechanical Ventilators"[tiab] OR "Pulmonary Ventilators"[tiab] OR "Pulmonary Ventilator"[tiab] OR "Respirators"[tiab] OR "Respirator"[tiab] OR "Ventilators"[tiab] OR "Ventilator"[tiab]) AND ("Nurses"[Mesh] OR "Nurses"[tiab] OR "Nurse"[tiab]) AND ("Nurses/education"[Mesh] OR "Nursing/education"[Mesh] OR "Students, Nursing"[Mesh] OR "nursing students"[tiab] OR "nursing student"[tiab] OR "nurse students"[tiab] OR "nurse student"[tiab] OR "novice nurses"[tiab] OR "novice nurse"[tiab] OR "Education"[Mesh] OR "Education"[tiab] OR "Educational"[tiab] OR "Education*"[tiab] OR "education programs"[tiab] OR "education program"[tiab] OR "education programme"[tiab] OR "education programmes"[tiab] OR "educational programs"[tiab] OR "educational program"[tiab] OR "educational programme"[tiab] OR "educational programmes"[tiab] OR "educational tool"[tiab] OR "educational tools"[tiab] OR "education tool"[tiab] OR "education tools"[tiab] OR "blended education"[tiab] OR "Training"[tiab] OR "Train"[tiab] OR "Trained"[tiab] OR "on-the-job training"[tiab] OR "on-the-job learning"[tiab] OR "practice training"[tiab] OR "practice learning"[tiab] OR "training tool"[tiab] OR "training tools"[tiab] OR "Curriculum"[tiab] OR "Curricula"[tiab] OR "Learning"[Mesh] OR "Learning"[tiab] OR "Learn"[tiab] OR "Learn*"[tiab] OR "Virtual Reality"[Mesh] OR "Virtual Reality"[tiab] OR "Educational Virtual Reality"[tiab] OR "patient simulators"[tiab] OR "patient simulator"[tiab] OR "patient simulation"[tiab] OR "virtual reality technology"[tiab] OR "VR technology"[tiab] OR "VR system"[tiab] OR "VR systems"[tiab] OR "Educational Technology"[Mesh] OR "Teaching"[Mesh] OR "Teaching"[tiab] OR "Teach"[tiab] OR "Teach*"[tiab] OR "Teaching Materials"[Mesh] OR "teaching tool"[tiab] OR "teaching tools"[tiab] OR "blended teaching"[tiab] OR "online lecture"[tiab] OR "online lectures"[tiab] OR "online learning"[tiab] OR "online education"[tiab] OR "online teaching"[tiab] OR "acquire skill"[tiab] OR "acquire skills"[tiab]) AND ("2000/01/01"[PDAT]: "3000/12/31"[PDAT]))