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The effectiveness of training programmes in reducing short peripheral intravenous catheter failures: A systematic review

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ABSTRACT

Aim: To assess and synthesise evidence on short peripheral intravenous catheter (sPVC) management training programmes and evaluate their effectiveness in reducing early sPVC failure in hospitalised patients.
Background: Modifiable risk factors, including choice of catheter, site of insertion, early recognition of complications and provider expertise, play a critical role in sPVC failure, highlighting the need for targeted educational programmes to improve provider skills and adherence to evidence-based practices.
Design: A systematic review was employed following the PRISMA guidelines.
Methods: A systematic search was conducted across four databases—PubMed, Embase, CINAHL and the Cochrane CENTRAL. Only randomized controlled trials (RCTs) evaluating training programmes for sPVC management in healthcare professionals, with outcomes related to sPVC failure, were included. Risk of bias was assessed using the Cochrane risk-of-bias tool for RCTs. The protocol was registered in PROSPERO (CRD42023444364) and the search covered studies published up to June 20, 2024.
Results: The search strategy retrieved 12,253 articles, of which three were included. These reported a significant reduction in sPVC failure in the intervention groups, with reductions ranging from 8 % to 29 %. However, no improvements were found in individual outcomes (occlusion, dislodgment, infiltration, infection). The included studies exhibited substantial heterogeneity in training programme characteristics, including duration, content and delivery methods.
Conclusion: Structured training programmes can help reduce sPVC failure rates, despite variations in programme implementation. Short- and long-term programmes showed benefits, with long-term training supporting sustained adherence to evidence-based practice despite requiring more resources. A small number of studies prevent definitive conclusions about overall effectiveness.

1. Introduction

The insertion of a short peripheral intravenous catheter (sPVC) is one of the most frequently performed invasive procedures in healthcare, commonly conducted by nurses and physicians globally (Alexandrou et al., 2018). Short peripheral intravenous catheters are typically the first option for patients who require intravenous drug administration and frequent blood sampling (Decker et al., 2016). However, sPVC use is frequently complicated by mechanical and chemical issues, including phlebitis, infiltration, occlusion, dislodgement and infections. Among these, phlebitis and infiltration are the most common, with a recent meta-analysis reporting phlebitis in 36 % of 7323 patients, while infiltration occurred in 20.5 % of 3638 patients when sPVCs were routinely replaced and 23.9 % of 3685 patients when replaced based on clinical indications (Webster et al., 2019). Less common complications include occlusions (18.8 %) and accidental removal (6.9 %), while catheter-related bloodstream infections are rare (Maki et al., 2006; Rickard et al., 2012).

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These complications are even more frequent among patients with difficult intravenous access, who often suffer from venous depletion caused by anatomical or health-related factors (Civetta et al., 2019). In such patients, sPVCs are more frequently inserted in less optimal locations, including the hands, wrists, ankles, feet, or external jugular veins. Unfortunately, these alternative sites not only increase patient discomfort but also significantly elevate the risk of complications, particularly phlebitis and infiltration (Mihala et al., 2018; Simin et al., 2019; Nickel et al., 2024).

2. Background

In a previous study, Marsh et al. identified risk factors for sPVC-related complications, suggesting that most of them are usually modifiable (Marsh et al., 2018). Among these, the use of a 22-gauge catheter, as opposed to a 20-gauge, was associated with a higher risk of infiltration and the placement of the catheter in the dominant limb or the administration of phlebitogenic medications increased the risk of phlebitis (Marsh et al., 2018). Limited knowledge and skills among healthcare providers were also identified as significant factors contributing to the failure and reduced lifespan of sPVCs (Keleekai et al., 2016). Enhancing nurses' expertise in areas —such as insertion site selection, catheter choice, fixation techniques, dwell time and early recognition of complications—is essential for improving sPVC longevity and patient outcomes (Cicolini et al., 2009; Hadaway, 2012). Evidence supports that improving these skills increases first-attempt success rates and reduces complications, particularly when procedures are performed by experienced nurses (Keleekai et al., 2016; Palefski and Stoddard, 2001). Consequently, targeted educational programmes might play a pivotal role in equipping nurses with the competencies required to deliver comprehensive, evidence-based care (Aziz, 2009; Lyons and Kasker, 2012). Since sPVC insertion is one of the most common procedures performed by nurses, it represents a fundamental clinical skill that should be consolidated and continuously updated through structured post-basic education and continuing professional development (Keleekai et al., 2016). Strengthening training at these levels ensures the maintenance of high clinical standards and aligns educational strategies with evidence-based practice, ultimately supporting the ongoing competence of the nursing workforce (Rycroft-Malone et al., 2013; Kitson and Harvey, 2016). Training programmes should promote adherence to clinical guidelines and, at the same time, take into account healthcare professionals' experiences and patient preferences (Kitson and Harvey, 2016; Greenhalgh et al., 2017). For instance, a recent meta-analysis found that simulation-based training improves skills in vascular access, PICC and radial artery catheter placement with better success rates than traditional methods, but its impact on reducing adverse events remains unclear (Okano et al., 2021)

Although numerous studies have examined the clinical complications associated with sPVCs (Marsh et al., 2018, 2021; Cicolini et al., 2009) and some have investigated the role of simulation-based training in vascular access (Keleekai et al., 2016; Simeone et al., 2023), there remains a knowledge gap due to the lack of a comprehensive synthesis specifically focused on structured training programmes aimed at reducing sPVC failure. Previous systematic reviews have primarily emphasized infection control or central venous catheter care (Foka et al., 2021), without addressing how educational interventions targeting sPVC insertion and management affect clinical outcomes. Moreover, current literature has yet to thoroughly evaluate how various training modalities—such as simulation, workshops, or blended learning—affect the success rate of sPVC catheter insertion in hospitalized patients (Stone et al., 2023).

To the best of our knowledge, no published or ongoing review has compiled evidence on this topic. This systematic review, therefore, aims to critically evaluate and synthesize the evidence on training programmes specifically designed for the management of sPVCs. By consolidating the available data, this study seeks to determine the overall effectiveness of these programmes in reducing early sPVC failure among hospitalized patients and to provide clear, evidence-based recommendations for future practice and research.

3. Methods

3.1. Data sources and searches

This systematic review of RCTs was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline (Page et al., 2021). The Cochrane Handbook for Systematic Reviews of Intervention was chosen as the methodological guidance (Higgins et al., 2019). The protocol was registered in PROSPERO (CRD42023444364) and published elsewhere (Privitera et al., 2023).

We searched PubMed, Embase, CINAHL and the Cochrane Central Register of Controlled Trials (CENTRAL) to identify relevant studies for inclusion. Observational studies were excluded to minimise bias and ensure a higher level of evidence, as randomised controlled trials provide more robust data for assessing the causal effects of interventions. We also reviewed the references of eligible studies to identify additional relevant works not captured in our initial search. Grey literature or conference abstracts were excluded. Searches were conducted for studies published up to June 20, 2024.

Medical Subject Headings (MeSH) and pertinent free-text terms were combined using Boolean operators (AND, OR) to identify studies featuring the appropriate intervention and study design (e.g., randomized controlled trials or controlled clinical trials). The search string is reported in the Supplementary Table 1.

3.2. Search methods for the identification of studies

No limitations were applied to the literature search and no year restrictions were applied. There were no language-based exclusions for studies and efforts were made to translate studies published in languages other than English and Italian.

3.3. Study selection criteria

3.3.1. Eligibility criteria

The research question was formulated using the PICO research question framework (Schardt et al., 2007):

- *Population*: healthcare professionals responsible for sPVC placement (physicians, nurses, midwives, etc.) working in wards caring for adult and pediatric patients were included. Studies involving students and professionals still to be qualified were excluded. No limits were based on the work setting (e.g., emergency, long-stay, outpatient, etc.);
- *Intervention*: any training programme focused on sPVC management with no restrictions on the duration or delivery method they were delivered;
- *Comparison*: eligible studies had to compare the effects of the training programme interventions with usual care. Studies comparing two active training interventions were excluded to maintain focus on the overall effectiveness of structured training VS standard practice or no training;
- *Outcomes*: The primary outcome was all-cause sPVC failure, defined as a composite of infiltration, thrombophlebitis, occlusion, dislodgement, catheter-related bloodstream infection and local infection. Infiltration was defined as the permeation of intravascular fluid into the interstitial compartment, causing tissue swelling around the catheter site (Nickel et al., 2024); thrombophlebitis, using any definition identified by the authors; occlusion as the inability and/or impossibility to infuse fluids through the catheter due to an obstruction (Santomauro et al., 2024); dislodgment, as the

catheter dislodgement (partial or complete) from the insertion site (Marsh et al., 2018); Catheter-related bloodstream infection (CRBSI), defined as a positive blood culture from a peripheral vein and/or colonised IV catheter tip culture with the same organism as identified in the blood in the presence of clinical signs of infection and without other apparent source of infection except for the IV catheter (Webster et al., 2019); local infection, as defined by the trial author.

Additionally, the following secondary outcomes were considered: pain during infusion, measured using any validated pain assessment scale; patients' or healthcare professionals' satisfaction, assessed by any validated satisfaction scale; dwell time, defined as the time interval between the insertion and removal of the sPVC (Wei et al., 2019); each complication included in the primary outcome (infiltration, thrombophlebitis, occlusion, dislodgement, local infection and catheter-related bloodstream infection) was considered separately as a secondary outcome;

- *Study design*: Only RCTs were included, as they offer the highest level of evidence for assessing the effectiveness of training interventions. RCTs minimise selection bias and enable causal inference. We excluded prospective and retrospective observational studies, case series and studies for which only the abstract was available, due to their higher risk of bias and lower methodological rigour.

3.3.2. Screening process and data extraction

Studies identified through electronic database searches were imported into Covidence software for data management and screening. Covidence was used to exclude duplicate studies in the initial phase. Two authors (P.D. and S.I.) independently screened the title and abstract, followed by a full-text review based on the eligibility criteria. Disagreements or conflicts were resolved by a third author (B.E). A planned standardised Excel spreadsheet was used to extract data (patients' characteristics, selection criteria, type of intervention, follow-up periods, outcome measures and main results).

3.4. Risk of bias assessment

Two authors (P.D. and B.I.) independently assessed the risk of bias (RoB) through the Revised Cochrane risk-of-bias tool for RCTs (RoB 2) (Sterne et al., 2019). The RoB 2 tool evaluates bias across five domains: the randomization process, deviations from intended interventions, missing outcome data, outcome measurement and the selection of reported results. Each domain, as well as the overall risk of bias, is classified into one of three categories: "low risk of bias," "some concerns," or "high risk of bias. Disagreements between reviewers in data extraction and assessments of RoB were resolved by third-party adjudication (S.I.). No studies were excluded based on the risk of bias evaluation.

3.5. Synthesis methods

Due to the limited number and the high heterogeneity of interventions, a meta-analysis was not feasible. Instead, we conducted a narrative synthesis. Data from each study were systematically summarized in a standardized table and a comprehensive analysis was structured using the PICO framework. When necessary, missing information was sought directly from the authors of the primary studies.

4. Results

4.1. Study selection

The search strategy retrieved 12,253 articles. After removing duplicates, 9998 articles were screened for title and abstract, excluding all but 10 records. These full texts were assessed for eligibility, with seven being excluded for the following reasons: incorrect study design (n = 1), unpublished paper (n = 3) and irrelevant outcomes (n = 3). A total of three RCTs were included (Blanco-Mavillard et al., 2021; Keogh et al., 2020; Lundgren and Wahren, 1999). A detailed selection process is shown in the PRISMA flowchart (Fig. 1).

4.2. Risk of bias assessment

Of the three included studies, two were judged as having a low RoB (Blanco-Mavillard et al., 2021; Keogh et al., 2020), while one was rated at high risk due to deviations from the intended interventions and issues related to outcome measurement (Lundgren and Wahren, 1999). Regarding missing outcome data, all studies were judged to have a low risk. RoB in outcomes measurements raised some concerns in two studies (Blanco-Mavillard et al., 2021; Keogh et al., 2020) and was classified as high risk in the third (Lundgren and Wahren, 1999). The RoB in the selection of reported outcomes was judged as low in one study (Blanco-Mavillard et al., 2021), with some concerns in another (Keogh et al., 2020) and high (Lundgren and Wahren, 1999) in the third. Overall, two of three RCTs were judged as having some concerns (Blanco-Mavillard et al., 2021; Keogh et al., 2020) and one was judged to have a high RoB (Lundgren and Wahren, 1999). Fig. 2, A and B, show a detailed evaluation of the methodological quality of the studies included.

4.3. Description of included studies

The studies took place in Spain (Blanco-Mavillard et al., 2021), Sweden (Lundgren and Wahren, 1999) and Australia (Keogh et al., 2020). Two RCTs used a cluster design—one with a step-wedge approach—while the third followed a parallel design (Lundgren and Wahren, 1999). Two studies were conducted at a single center (Keogh et al., 2020; Lundgren and Wahren, 1999) and one was a multicenter study (Blanco-Mavillard et al., 2021). The settings included medical and surgical wards (Keogh et al., 2020; Lundgren and Wahren, 1999), with one also extending to an oncology ward (Blanco-Mavillard et al., 2021). The studies enrolled between 99 and 4478 patients, with the number of analyzed sPVCs ranging from 172 to 4565. The main characteristics of the included studies are summarized in Table 1.

4.3.1. Description of the training programmes

The training programmes were designed for different target groups: nurses only (Lundgren and Wahren, 1999), nurses and doctors (Keogh et al., 2020), or nurses and patients (Blanco-Mavillard et al., 2021). The duration varied across studies, with one study conducting three sessions over a four-month period (Lundgren and Wahren, 1999), another implementing a two-week supportive program (Keogh et al., 2020) and the third extending training over 12 months (Blanco-Mavillard et al., 2021).

All programmes offered theoretical education based on the latest clinical practice guideline recommendations. However, while two studies covered broader management of sPVCs, including insertion, maintenance and removal (Blanco-Mavillard et al., 2021; Lundgren and Wahren, 1999), one study focused specifically on flushing practices (Keogh et al., 2020). Moreover, the studies employed different instructional strategies, including case study discussions (Lundgren and Wahren, 1999), verbal presentations of guidelines during shift handovers (Keogh et al., 2020), or a self-directed e-learning approach (i.e., video) combined with a teaching program led by sPVC experts, along with the dissemination of up-to-date protocols and posters (Blanco-Mavillard et al., 2021). To facilitate adherence to recommendations, Blanco-Mavillard et al. incorporated regular performance feedback and the support of local facilitators (Blanco-Mavillard et al., 2021). Local facilitators included patient representatives, healthcare professionals, lead nurse researchers and managers, ensuring a multidisciplinary approach to reinforcing best practices. Two programmes also included practical demonstrations: one focused on flushing an sPVC (Keogh et al., 2020), while the other covered insertion and fixation techniques (Lundgren and Wahren, 1999).

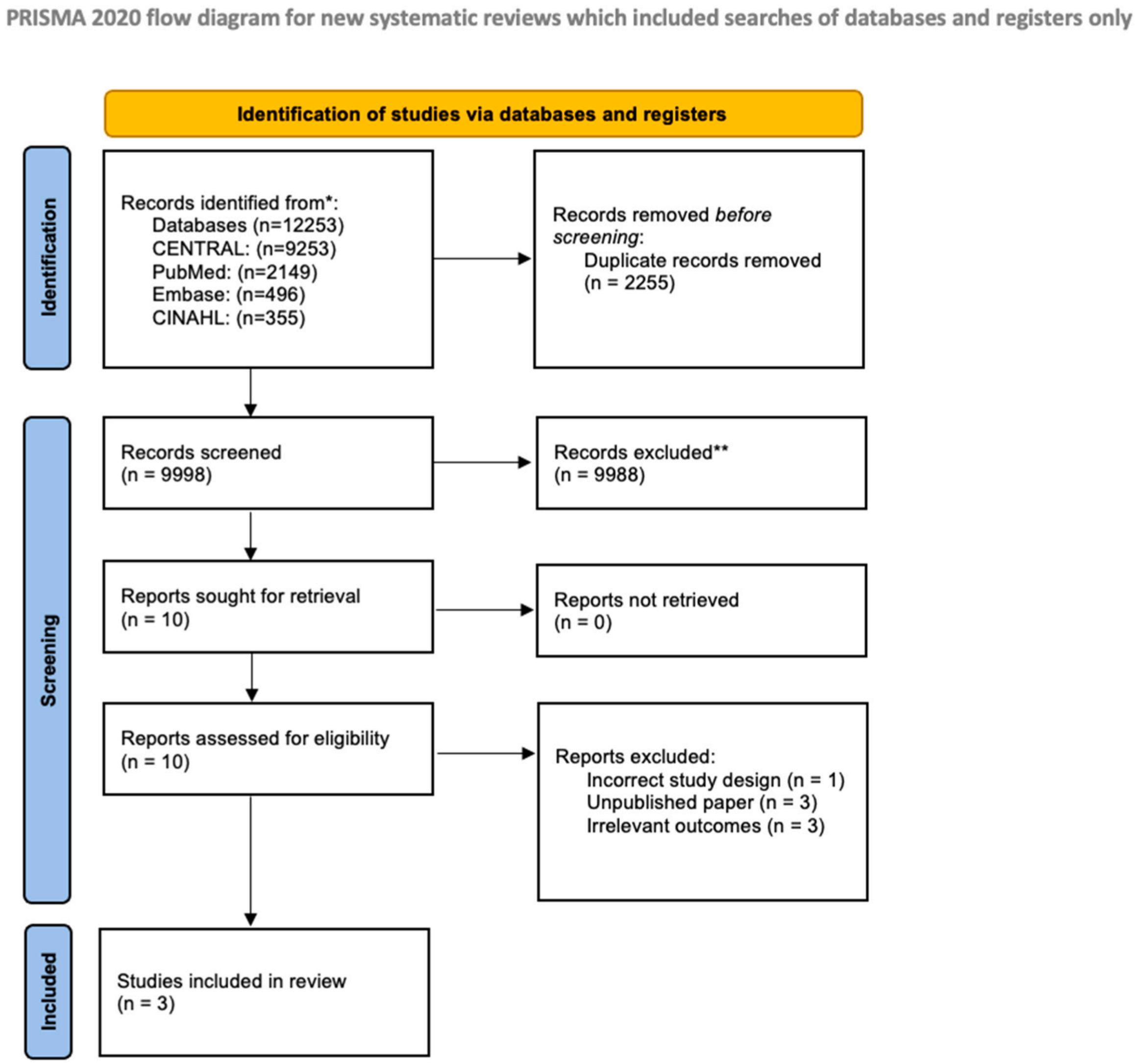

Fig. 1. PRISMA flow diagram.

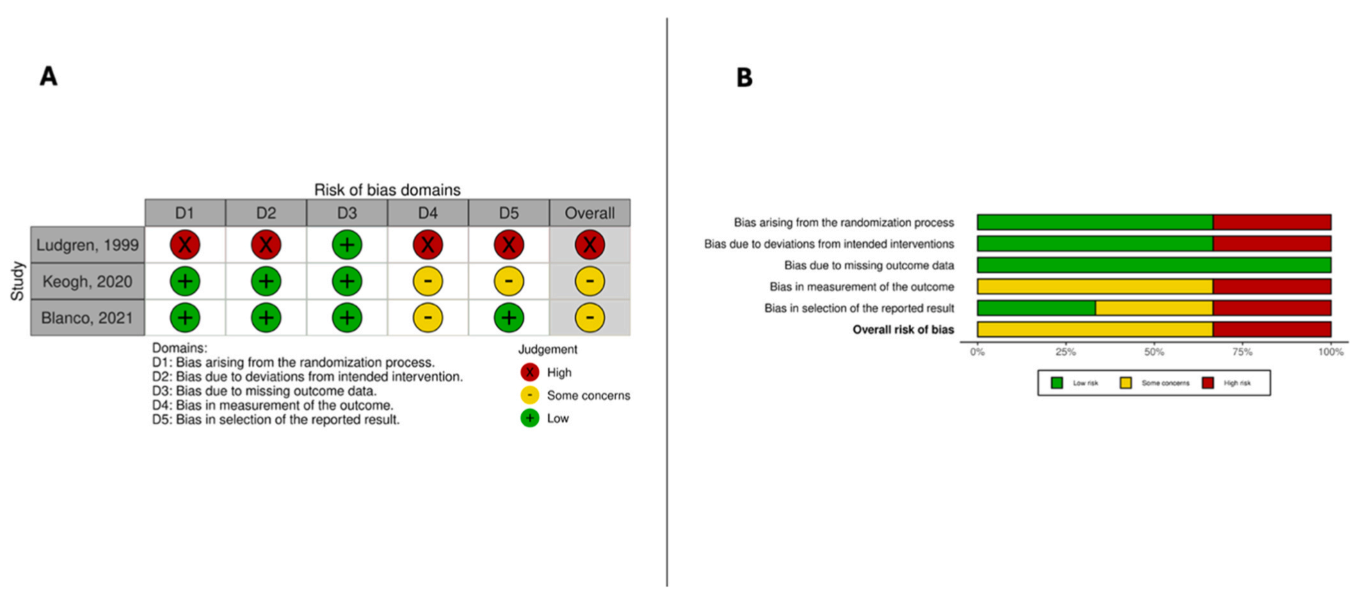

Fig. 2. (A) Traffic light graph with authors' judgement about bias domains. (B) Risk of bias graph: judgments about each risk of bias item presented as percentages across all included studies.

Table 1
Characteristics of the included studies.

First author, year of publication, and country	Study design	Setting	Subject enrolled	Subjects of education	Intervention *Educational strategies (Duration)*	Educational content focus areas	Control	Outcomes	Follow up (months)	Main results
Lundgren et al. *1999* Sweden	Parallel RCT	1 hospital 2 medical 2 surgical wards	**Intervention** 60 patients Mean age 70 (± 13) 112 sPVC 18 nurses **Control** 33 patients Mean age 68 (± 18) 60 sPVC 18 nurses	Nurses	Practical training Case studies discussion Standardized documentation form for recording care practice (4 months)	PIVC insertion, maintenance, and removal. Documentation care	Unspecified	**Thrombophlebitis** Patient Awareness-Satisfaction	4 months	i) Reduced thrombophlebitis rate in the intervention group compared to the control group (21 % VS 50 %, $p < 0.001$) ii) Patients on the intervention group understood significantly more information than control group ($p < 0.001$).
Keogh et al. *2020* Australia	Stepped wedge cluster RCT	1 hospital 9 medical, 9 surgical ward	**Intervention** 313 patients Mean age 58 (± 19) 313 sPVC **Control** 306 patients Mean age 60 (± 19) 306 sPVC	Nurses and doctors	Verbal presentation of the guidelines during shift handover Hands-on demonstration of pre-filled flush syringe usage Study information emailed to professionals (2 weeks)	Flushing practice	Manually prepared syringes with 0.9 % sodium chloride of varying volumes, or infusions from 100 mL or 1000 mL 0.9 % sodium chloride bags Routinely at 72–96 h replacement was in practice	**sPVC failure** Leakage Occlusion Infiltration Dislodgement Infection Phlebitis sPVC dwell time	1 month	i) Reduced sPVC failure in the intervention group compared to the control group (22 % VS 30 %, $p = 0.03$) ii) Reduced leakage rate in the intervention group compared to the control group (2 % VS 6 %, $p = 0.03$) iii) No difference in the occlusion rate between groups (6 % VS 6 %, $p = 0.90$) (iv) No difference in the infiltration rate between groups (10 % VS 13 %, $p = 0.28$) (v) No difference in dislodgement rate between groups (6 % VS 7 %, $p = 0.59$) (vi) No difference in infection rate between groups (1 % VS 1 %, $p = 0.98$) (vii) No difference in phlebitis rate between groups (5 % VS 9 %, $p = 0.11$) (viii) No difference in sPVC dwell time between groups (785 V% 828

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Table 1 (*continued*)

First author, year of publication, and country	Study design	Setting	Subject enrolled	Subjects of education	Intervention *Educational strategies (Duration)*	Educational content focus areas	Control	Outcomes	Follow up (months)	Main results
										accumulative days, $p = 0.25$)
Blanco-Mavillard et al. *2021* Spain	Cluster RCT	7 hospitals 12 medical, 8 surgical, 2 oncology wards	**Intervention** 2196 patients Median age 69 (65–70) 2235 sPIVCs 131 nurses **Control** 2282 patients Median age 70 (65–73) 2330 sPIVCs, 138 nurses	Nurses Patients	Self-direct e-learning Face-to-face training sessions Up-to-date protocols, Posters and video Regular feedback on performance and Local facilitators (12 months) Leaflets	Hygiene, aseptic measures, insertion, maintenance, and removal of PVCs	72–96 h routinely replacement of PIVCs was not in practice	**sPVC failure** Phlebitis Extravasation Occlusion Dislodgment Catheter-related bloodstream infection sPVC dwell time Nurse satisfaction	12 months	i) Reduced sPVC failure in the intervention group compared to the control group (HR 0·81 VS HR 1.21, $p < 0.0001$; mean difference (IC 95 %) –9·39 % (–11·22 to –7·57) (ii) Reduced phlebitis rate in the intervention group compared to the control group (13·08 % VS 16·66 %, $p = 0{\cdot}037$) (iii) Reduced extravasation in the intervention group compared to the control group (15·93 % VS 18·73 %, $p = 0.045$) (iv) No difference in obstruction rate between the groups (4·46 % VS 5·67 %, $p = 0.157$) (v) No difference in dislodgment rate between groups (3·63 % VS 5·43 %, $p = 0.170$) (vi) No difference in catheter-related bloodstream infection rate between groups (0.0–0·12 %, $p = 0.329$) (vii) Reduced sPVC dwell time in the intervention group compared to the control group (70 VS 90 h, $p = 0.012$) viii) Educational intervention was useful, increased

(*continued on next page*)

Table 1 (*continued*)

First author, year of publication, and country	Study design	Setting	Subject enrolled	Subjects of education	Intervention *Educational strategies (Duration)*	Educational content focus areas	Control	Outcomes	Follow up (months)	Main results
										awareness of flushing guidelines, and highly rated pre-filled flush syringes for utility and confidence.

In bold the primary outcome;
sPVC, short peripheral venous catheter.

4.4. sPVC failure

All three studies examined sPVC failure. Blanco-Mavillard et al. defined sPVC failure as resulting from phlebitis, extravasation, obstruction, dislodgement, or infection (Blanco-Mavillard et al., 2021). Keogh et al. analyzed similar variables but assessed infiltration (fluid leakage into surrounding tissues) instead of extravasation (inadvertent leakage of a vesicant solution into surrounding tissue) (Keogh et al., 2020). In contrast, one study considered phlebitis as the sole reason for sPVC failure (Lundgren and Wahren, 1999). All three studies reported a significant reduction in sPVC failure in the intervention group compared with the control group.

4.5. Phlebitis

All three studies assessed the effectiveness of training programmes in reducing phlebitis. However, only one study reported an improvement in the intervention group (Lundgren and Wahren, 1999), while the others found no significant differences.

4.6. Occlusion

Two studies Blanco-Mavillard et al., 2021; Keogh et al., 2020) assessed the occlusion rate, but neither found a significant difference in favor of the intervention compared with the control group.

4.7. Dislodgment

Two studies evaluated the dislodgment rate, but neither found a significant difference favoring the intervention (Blanco-Mavillard et al., 2021; Keogh et al., 2020).

4.8. Infiltration and extravasation

Only Keogh et al. one study assessed infiltration (Keogh et al., 2020), while Blanco-Mavillard et al. focused solely on extravasation (Blanco-Mavillard et al., 2021). The first found no difference between the intervention and control groups, whereas Blanco-Mavillard et al. reported a significantly lower extravasation rate in the intervention group compared with the control group.

4.9. Infection

Two studies assessed infection rates. Keogh et al. found no sPVC-related bloodstream infections in either group (Keogh et al., 2020). Similarly, Blanco-Mavillard et al. reported three cases (0.1 %) in the control group but none in the intervention group (Blanco-Mavillard et al., 2021).

4.10. Dwell time

Two studies included dwell time as a secondary outcome, but only one analyzed all sPVCs in place for 24 h or less (Lundgren and Wahren, 1999). Keogh et al. found no difference between groups (Keogh et al., 2020), while Blanco-Mavillard et al. reported a significantly shorter median dwell time in intervention sites compared with control sites (75 h [IQR 50–110] vs 90 h [IQR 60–115]; $p < 0.0001$) (Blanco-Mavillard et al., 2021).

4.11. Satisfaction

Two trials included satisfaction as a secondary outcome (Keogh et al., 2020; Lundgren and Wahren, 1999). In the study by Lundgren et al., satisfaction was assessed specifically in terms of the patient's awareness of the purpose of the sPVC and their understanding of how it would be managed. Patients in the intervention group reported higher levels of satisfaction than those in the control group ($p < 0.001$). However, the results showed that most patients still had a limited understanding of their condition, the need for sPVC placement and how to use the device correctly (Lundgren and Wahren, 1999). Keogh et al. assessed staff satisfaction using a study-specific survey evaluating product usage, utility and the impact of the educational intervention (Keogh et al., 2020). In this case, ward nurse satisfaction scores were generally high for both the educational intervention and the use of manufacturer-prepared pre-filled flush syringes.

4.12. Pain during infusion

None of the studies in this review had included pain during infusion as an outcome.

5. Discussion

This systematic review assessed the impact of training programmes for healthcare professionals on reducing the sPVC failure rates. By analyzing three RCTs, the study explored how structured training programmes might improve clinical outcomes.

Our findings align with prior research suggesting that tailored training programmes might mitigate complications through enhanced technical skills and adherence to evidence-based practices. For instance, Rickard et al. emphasized the role of education in reducing phlebitis, which are common reasons for catheter failure (Rickard and Ray-Barruel, 2017). In a previous non-randomized controlled trial, Takahashi et al. demonstrated that using a specific care protocol might reduce the sPVC failure (Takahashi et al., 2020), or similarly, the cross-sectional study conducted by Alexandrou et al. highlighted that targeted interventions improve first-pass success rates and reduce complications such as occlusion and infection (Alexandrou et al., 2018). Furthermore, the results of this systematic review are consistent with the secondary analysis conducted by Marsh et al., which showed that complications such as dislodgement can be significantly reduced when sPVCs are inserted by a dedicated vascular access team of trained and specialised healthcare professionals (Marsh et al., 2021).

The educational strategies varied significantly in their implementation. For instance, Blanco-Mavillard et al. introduced a versatile approach by integrating face-to-face lectures with e-learning modules (Blanco-Mavillard et al., 2021). Supporting this approach, a recent systematic review confirmed that e-learning effectively bridged the gap between knowledge and practice while supporting the professional development of registered nurses in healthcare (Alfaleh et al., 2023). Additionally, e-learning can foster a conducive environment for interaction between learners and facilitators, making the learning process both stimulating and engaging (Regmi and Jones, 2020).

Simulation-based learning was largely absent across the reviewed studies, with Keogh et al.'s research offering a partial exception. Their approach uniquely incorporated direct training from a Becton Dickinson (BD Medical) industry representative, who instructed staff on the use of pre-filled syringes specific to the manufacturer (Keogh et al., 2020). However, even in this study, comprehensive simulations addressing broader aspects of sPVC handling remained limited (Keogh et al., 2020). Several studies incorporating simulation-based learning reported greater efficacy in reducing sPVC failure rates than those relying solely on didactic teaching. For instance, Keleekai et al. found that nurses who underwent a simulation-based blended learning program exhibited significant improvements in sPVC insertion knowledge, confidence and skills compared with those receiving traditional training methods (Keleekai et al., 2016). Similarly, a before-after study concluded that simulation-based teaching effectively developed nursing students' sPVC skills and increased their self-confidence (Jallad, 2024). These findings suggest that integrating simulation into training programmes may further reduce complications associated with sPIVC procedures.

Another key difference among the three studies was the duration of the training programme. Contrary to expectations, both short-term and long-term programmes demonstrated meaningful benefits, though they differed in sustainability and feasibility of implementation. Blanco-Mavillard et al.'s 12-month multimodal intervention study serves as a compelling example of extended educational strategies. Their comprehensive approach successfully reduced sPVC failure rates from 46.5 % to 37.1 %, suggesting that prolonged interventions can facilitate deeper organizational learning and cultural transformation (Blanco-Mavillard et al., 2021). The extended duration appeared to support a more profound integration of evidence-based practices, enabling healthcare teams to internalize and consistently apply improved clinical techniques (Duff et al., 2020).

However, the potential advantages of long-term programmes must be critically balanced against their substantial resource requirements. Such extensive interventions demand significant investments of time, personnel and organizational commitment, which may pose challenges in resource-limited healthcare settings or under strict budgetary constraints (Lenihan et al., 2019; Giovanelli et al., 2024).

On the other hand, short-term training programmes have also shown promising results through targeted and intensive interventions (Keogh et al., 2020; Lundgren and Wahren, 1999). Their effectiveness is particularly evident when incorporating practical tools and easy-to-follow protocols (Keogh et al., 2020; Lundgren and Wahren, 1999). However, maintaining these improvements over time remains a challenge. Without periodic follow-up or reinforcement, adherence to guidelines might decline (Ivers et al., 2012).

Despite differences in the delivery methods and duration of the training programmes, the interventions also revealed fundamental commonalities. For example, across the different approaches, programmes always prioritised improving technical skills and promoting strict adherence to evidence-based clinical practice. Feedback and reinforcement mechanisms emerged as critical components in sustaining adherence to recommended practices. Blanco-Mavillard et al. implemented regular performance feedback sessions to monitor and improve compliance and Keogh et al. reinforced learning through dynamic demonstrations and comprehensive resource dissemination. Although Lundgren et al. did not explicitly outline formal feedback systems, their use of standardized documentation likely provided an indirect mechanism for participant performance evaluation and continuous improvement. Several implementation studies have reinforced the importance of ongoing feedback and follow-up (Hysong, 2009). For instance, educational projects that incorporate regular audits and practical reinforcement have shown that combining brief initial training with periodic feedback can achieve outcomes similar to longer programmes, maintaining a balance between effectiveness and operational feasibility (Ivers et al., 2012; Grol and Grimshaw, 2003).

The lack of significant improvements in individual complications and other secondary outcomes, such as occlusion, dislodgment and infiltration, may be due to the limited statistical power of the included studies.

The three studies present differing perspectives on dwell time and its impact on sPIVC outcomes. Keogh et al. demonstrated that dwell time can be safely extended with rigorous maintenance practices, such as flushing and site inspection. Similarly, Blanco-Mavillard et al. showed that longer dwell times are not inherently detrimental when combined with evidence-based care protocols. On the contrary, Lundgren et al. linked extended catheter use to higher complication rates, such as phlebitis and therefore restricted their evaluation to sPVCs with dwell times under 24 h. In contrast, the other two studies did not impose this restriction, instead favoring clinical replacement based on patient need, with routine replacement occurring only after 72–96 h of catheter placement. Additionally, a recent meta-analysis found no significant difference in sPVC failure rates between clinical and routine replacement (Webster et al., 2019).

Although the review suggested a reduction in sPVC failure rates in intervention groups compared with standard care—regardless of the training program's duration, mode, or type—definitive conclusions cannot be drawn due to the limited number of included studies. For this reason, future research is necessary to confirm these preliminary results and provide more conclusive evidence on the effectiveness of training programmes in reducing specific complications.

The findings of this review suggest that structured training programmes might meaningfully reduce sPVC failure rates, thereby improving patient safety and care quality. These results have relevant educational implications, advocating for the integration of standardized training modules on vascular access management into both undergraduate nursing curricula and ongoing professional development initiatives. Hospitals and healthcare organizations should consider implementing simulation-based and blended learning programmes, specifically tailored to the needs of different care settings, to enhance competencies in vascular access management. Importantly, the effectiveness of such interventions is strongly influenced by specific training design elements: simulation and blended learning approaches have been shown to strengthen competence and confidence among students and novice practitioners (Keleekai et al., 2016; Marsh et al., 2021), while reinforcement mechanisms such as audit and feedback are essential to sustain long-term adherence to evidence-based practice (Blanco-Mavillard et al., 2021; Ivers et al., 2012). Future programmes should therefore prioritise these features to maximise both immediate effectiveness and sustainability.

These findings reinforce the centrality of nursing education practice in shaping clinical competence and patient safety. Embedding vascular access training within nursing curricula and lifelong learning frameworks ensures that educational interventions translate effectively into improved care outcomes. For clinical education, this implies that vascular access competencies should be introduced early in undergraduate curricula through simulation and blended learning and reinforced in continuing professional development for the existing workforce (Okano et al., 2021; Al-Omary et al., 2024; Bahl et al., 2024; Mitchell and Ivimey-Cook, 2023). At the international level, structured and scalable approaches—such as e-learning and short workshops—could be particularly valuable in resource-limited settings, where complication rates are often higher (Mihala et al., 2018; Regmi and Jones, 2020). Thus, training in sPVC management should be seen not only as a local quality-improvement initiative but as a global strategy to harmonise vascular access care and improve patient outcomes.

5.1. Strengths and limitations

This systematic review offers several notable strengths that contribute to its scientific value. By including only RCTs, it minimized potential biases inherent in observational studies. Additionally, its comprehensive assessment encompassed a wide range of sPVC complications, providing a nuanced and multidimensional perspective on the potential impact of educational interventions.

However, the review also confronts significant methodological limitations. One critical challenge emerged from the substantial temporal disparity among the included studies, with one study dating back to 1999—approximately two decades earlier than the others. This significant chronological gap introduced profound heterogeneity in scientific evidence, clinical guidelines and training methodologies. Over this period, healthcare practices, technological capabilities and educational approaches have evolved deeply, making direct comparisons difficult.

The included studies exhibited substantial heterogeneity in training programme characteristics, including duration, content and delivery methods. As a result, a meta-analysis was not feasible due to critical methodological disparities that could compromise statistical validity. These inconsistencies extended across multiple aspects, including non-standardized outcome measurements, varied educational approaches and inconsistent complication definitions. The narrative synthesis approach emerged as the most appropriate method to integrate and interpret the available evidence, acknowledging the inherent limitations of the current research landscape.

6. Conclusion

This review suggests that structured training programmes may contribute to reducing sPVC failure rates. Despite variations in programme implementation, the reduction in sPVC failure highlights the value of tailored training. Short- and long-term programmes demonstrated benefits, with long-term interventions promoting sustained adherence to evidence-based practice, although they require significant resources. The absence of simulation-based learning might be a notable gap, as evidence suggests that it can improve skills and confidence.

While the review provides valuable insights, the restricted number of studies prevents drawing definitive, robust conclusions about the universal effectiveness of training programmes in reducing sPVC complications. Future studies should explore the long-term effects of training and establish the optimal frequency and format for such programs.

CRediT authorship contribution statement

Daniele Privitera: Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Ines Basso:** Writing – review & editing, Methodology, Investigation, Data curation. **Isabella Santomauro:** Writing – review & editing, Methodology, Investigation, Data curation. **Erika Bassi:** Writing – review & editing, Methodology, Investigation, Data curation. **Nicolò Capsoni:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation. **Lucrezia Rovati:** Writing – review & editing, Methodology, Investigation, Data curation. **Alberto Dal Molin:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.nepr.2025.104608.

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