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Systematic Review

Educational programs for implementing ultrasound guided peripheral intravenous catheter insertion in emergency departments: A systematic integrative literature review

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ABSTRACT

Background: Ultrasound-guided peripheral intravenous catheter insertion has been identified as an effective method to improve the success rate of cannulation, thereby improving patient experience. However, learning this new skill is complex, and involves training clinicians from a variety of backgrounds. The aim of this study was to appraise and compare literature on educational methods in the emergency setting used to support ultrasound guided peripheral intravenous catheter insertion by different clinicians, and how effective these current methods are.
Review methods: A systematic integrative review was undertaken using Whittemore and Knafl's five stage approach. The Mixed Methods Appraisal Tool was used to assess the quality of the studies.
Results: Forty-five studies met the inclusion criteria, with five themes identified. These were: the variety of educational methods and approaches; the effectiveness of the different educational methods; barriers and facilitators of education; clinician competency assessments and pathways; clinician confidence assessment and pathways.
Conclusions: This review demonstrates that a variety of educational methods are being used in successfully training emergency department clinicians in using ultrasound guidance for peripheral intravenous catheter insertion. Furthermore, this training has resulted in safer and more effective vascular access. However, it is evident that there is a lack of consistency of formalised education programs available. A standardised formal education program and increased availability of ultrasound machines in the emergency department will ensure consistent practices are maintained, retained, therefore leading to safer practice as well as more satisfied patients.

1. Introduction

Peripheral intravenous access is often imperative for patients presenting to the emergency department (ED), to administer intravenous medications (IV) or fluids, obtain blood samples, or perform advanced life support fluid resuscitation [1–4]. Peripheral IV catheter (PIVC) insertion is one of the most common invasive procedures performed in ED, with up to 70 % of patients requiring a PIVC during their stay in hospital [4,5]. However, around one third of patients experience difficult intravenous access because of a range of clinical factors including presenting condition (e.g., dehydration, vascular pathology, obesity, history of intravenous drug use, age extremes, chronic illness, and clinical expertise) [3,6–8]. These patients often experience multiple painful PIVC insertion attempts by clinicians [2], lengthy delays in the

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diagnosis and treatment processes, and further complications such as infections, escalation to more invasive devices such as central venous catheters [CVCs] [9–12].

Ultrasound guidance (USG) has been proposed to assist placement of PIVCs, in comparison to using traditional landmarks on the body's surface [6,11,13]. USG-PIVC placement has been shown to reduce the number of percutaneous punctures with over 80 % successful insertion at the first attempt [14]. This has resulted in time efficiencies (almost half the time of standard of care (SOC)), reduced central venous access (CVC) use and increased patient satisfaction (average of > 7.5 out of 10) [2,11,14,15]. To facilitate effective USG use for PIVC insertion, training of ED clinicians in this vital skill is becoming increasingly common. However, the most effective educational delivery methods to provide this education remain unclear [16], potentially impacting the adoption and utilisation of this skill.

Currently, the most effective and sustainable approach to USG-PIVC education is undefined. The published research on USG-PIVC training is predominately physician focussed and limited in rigor and certainty [17]. In addition, there are no formal national educational USG-PIVC standards for ED clinicians in many countries including Australia, Spain and the United Kingdom [18,19]. In 2013, the World Congress of Vascular Access provided definitions and recommendations for training for CVC insertion using USG. However, there is little evidence of similar standards of practice in USG-PIVC insertion in any clinical context [20]. Determining the most effective and appropriate education strategy when implementing this complex skill to such a diverse cohort of clinicians will impact the feasibility and longevity of using USG for PIVC insertion in the ED.

2. Aim of review

The aim of this review is to appraise and compare literature on the current educational methods in the emergency setting when using USG-PIVC insertion on patients by different clinicians, and how effective these current methods are.

3. Methods

3.1. Design

A systematic integrative methodological review (IR) framework was utilised, allowing inclusion of all research designs including experimental and non-experimental studies [21]. Consistent with the framework, the stages of the review were: (1) Problem identification, as outlined in the introduction; (2) literature search; (3) data evaluation; (4) data analysis and (5) data interpretation and presentation of results [21]. The PRISMA statement was used to structure the review and systematically report findings [22] Fig. 1. and registered with PROSPERO: CRD42020204721 International prospective register of systematic reviews.

The review was guided by the following research questions:

1. What educational methods are used in the ED when teaching clinicians to insert PIVCs using USG?
2. What criteria are used to measure the effectiveness of USG PIVC education in the ED, from an organisational, clinician and patient perspective?
3. What are the barriers and facilitators of education in USG-PIVC insertion in ED?
4. After education, how is the competency of ED clinicians in using USG-PIVC insertion assessed? And, what is their competency pathway?
5. After education, how is the confidence of the ED clinicians in using USG-PIVC insertion assessed? And, what is their confidence pathway?

3.2. Search strategy

With the assistance of a university librarian, a systematic search using medical subject headings (MeSH) of "intravenous, peripheral" AND "ultrasound OR ultrasonography" AND "emergency" was conducted in the period of July 2020 and repeated July 2021. The search accessed the following databases: Cumulative Index to Nursing and Allied Health Literature (CINAHL), Medical Literature Analysis and Retrieval System Online (MEDLINE), PubMed, Scopus, Excerpta Medica database (EMBASE), The Cochrane Central Register of Controlled Trials (CENTRAL). Hand searching bibliographies was also undertaken. Inclusion and exclusion criteria are outlined in Table 1. Studies published in English and with no date limit were considered. Duplicates were removed and articles were screened against inclusion and exclusion criteria by paired study authors (RS with either AJU, RMW or NM).

3.3. Data extraction and quality appraisal

Eligible articles were independently reviewed in full text by first author (RS) first followed by a second author (RMW, NM or AJU). Once consensus was reached, data were extracted using a standardised form that included study author/ country/ year, design, sample/ methods, educational delivery/ method, and main findings. The methodological quality of articles was evaluated using the Mixed Methods Appraisal Tool [23] by first author (RS) and among the three authors (AJU, RMW or NM). All papers were again reviewed, with any discrepancies discussed and resolved within the team.

3.4. Data synthesis

Data were organised systematically into a data spreadsheet, identifying recurring themes to identify commonalities and variances in the data. An inductive approach using a thematic analysis within the literature was used to develop theories from patterns observed [24,25]. The first author (RS) assigned themes to emerging similarities. These identified themes were compared and subsequently organised into categories that answered the review questions.

4. Results

4.1. Study selection

Fig. 1 shows the studies included in this review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [26]. The search yielded an initial result of 1638 articles. A secondary hand search included screening of reference lists and google scholar yielding no further articles. Once duplicates were removed, 1148 papers' titles and abstracts were screened, resulting in 128 studies. The full texts of these 128 studies were assessed by (RS, AJU, NM, RW) for eligibility against the inclusion criteria, resulting in 45 papers being included in the final analysis.

4.2. Study characteristics

Individual study characteristics are displayed (see online Table 2). Studies included in the review were published between 1999 and 2022, with 37 articles published after 2010. The studies emanated primarily from the United States of America (USA) (n = 40), with two studies from Australia [27,28], one each from Turkey [29] Spain [19] and the United Kingdom [30]. The study designs were heterogenous, ranging from randomised controlled trials (RCTs) to quality improvement studies, and one peer reviewed letter to the editor. The most common design were prospective observational studies.

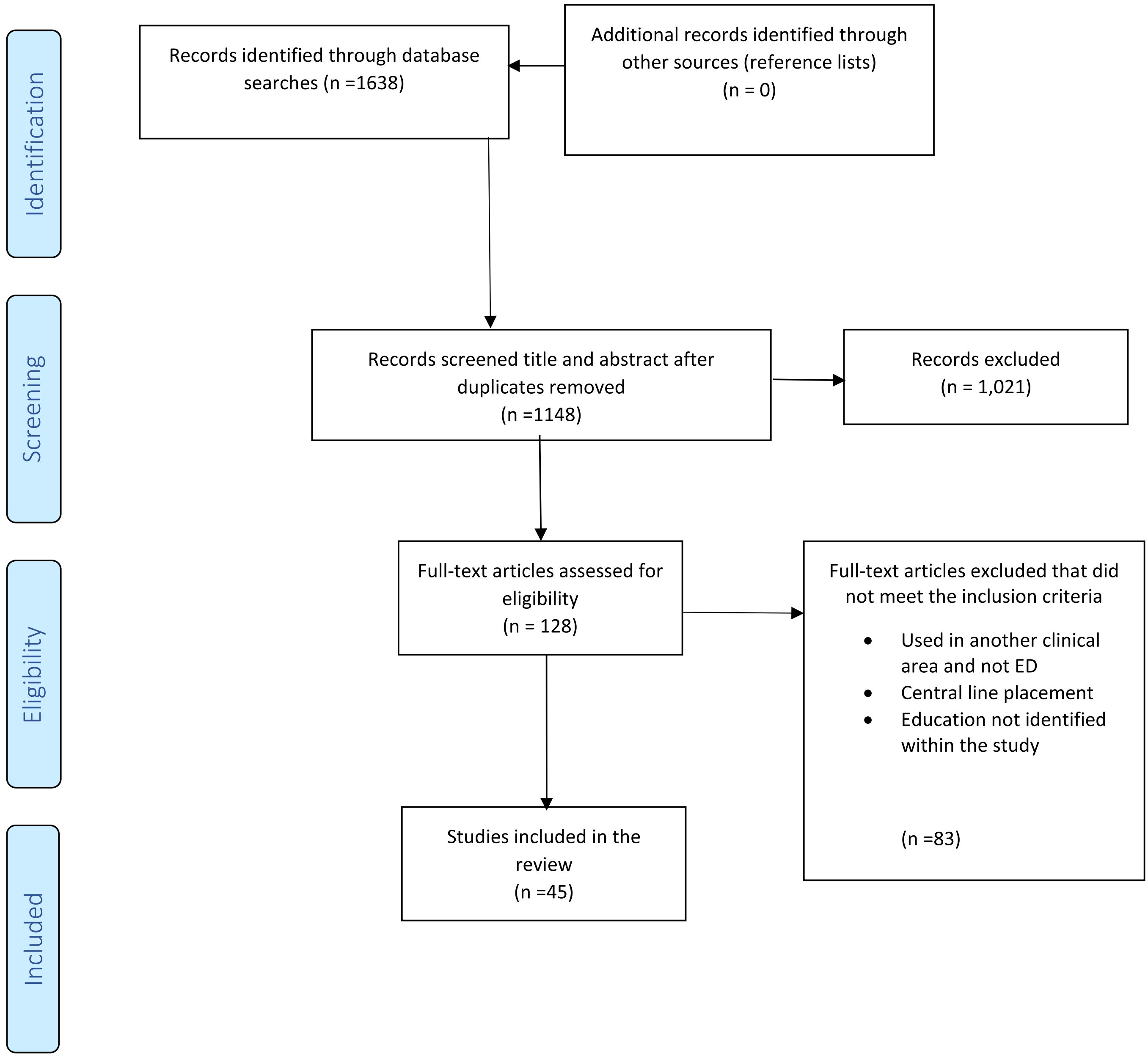

Fig. 1. Prisma Flow diagram provides the process undertaken to identify papers for review. Page et al. [22].

There were a broad spread of sample sizes ranging from five physicians being trained in one study [13] up to 195 clinicians including doctors, nurses, students and educators in another study [27,28]. Out of the 45 studies that were reviewed there were 34 studies that involved nurses being trained in using USG-PIVC. Of these 34 the USA was the main country where these studies were based. Participant sample sizes also varied with 50 [7] to 418 paediatric participants [31] and 18 [32] to > 4000 in adult studies [33].

4.3. Critical appraisal and quality assessment

The quality assessment for each article, expressed as MMAT [23] is reported (see online Table 1). While most studies were prospective observational cohort studies, they often required clinicians to self-report on their experience through a survey after attempting the procedure, which may have resulted in recall bias [34]. Additionally, some studies reported retrospective data (e.g., charts and electronic medical records) that may have been unreliable due to data input errors, introduced selection bias and misclassification or information bias [34].

4.4. Comparative findings

Findings are organised by themes.

4.4.1. The variety of educational methods and approaches for USG-PIVC insertion in ED

The educational methods used in most studies comprised both traditional face-to-face didactic methods and practical “hands-on” simulation (SIM) sessions. The amount of time dedicated to the training sessions for both methods varied significantly, ranging from 45 min [6,35] up to 20 h [19], with an average training time of approximately 160 min. Didactic sessions ranged from 30 min of delivery time [33,36] up to 15 h over a 15-week period for residents

Table 1
Inclusion and exclusion criteria.

Publication Inclusion Criteria
• English language • Adult and paediatric patients • Health care clinicians for example medical doctors, nurses, ED technicians, respiratory technicians, allied health technicians • Educational/instructional method reported • ED setting • USG-PIVC insertion • Primary studies including qualitative & quantitative methods
Publication Exclusion Criteria
• Non-English language • Non-peer-reviewed literature • Systematic Reviews • Non-emergency clinical setting • Landmark approach not USG • Other vascular access devices (e.g., CVC)

during their ED rotation [11]. SIM session times were not always noted and often varied depending on the clinician's requirements ranging from approximately 30 min for one group of physicians [37] to 4 h in other sessions for groups of nurses [33,38]. There were only three studies that used human models to visualise vessels and 18 studies used inanimate vascular-access arm models (e.g. Blue Phantom ® by CAE Healthcare) for clinicians to practice USG PIVC insertion [15,39,40,74]. Didactic educational sessions mainly used videos and slide presentations on topics including vascular anatomy, ultrasound physics, vascular access techniques, ultrasound machine operation including knobology and probe selection. SIM sessions involved practical training for clinicians on how to use ultrasound equipment [9,39,41,74], such as visualisation on an US screen to insert a PIVC [31].

4.4.2. The effectiveness of the different USG-PIVC education methods

The main measures of USG-PIVC education effectiveness were cannulation success rate (n or % of studies), [6,7,9–11,13,17,19,27,29,31–33,35–38,40–58,74] and time taken to cannulate (n or % of studies) [7,9–11,13,32,43,44,46,49,50,53,54,58,59,74]. Clinician feedback and patient satisfaction were also used to evaluate effectiveness.

First attempt insertion success ranged from 60 % from a sample size of 10 patients [32] up to 88 % with a much larger sample size of 2973 patients [41]. In one study, Ismailoglu and colleagues' descriptive study [29] reported a 70 % success rate for USG-PIVC compared to 30 % success rate for landmark insertion. However, in another study where USG-PIVC single operator versus dual operator technique was examined displaying no significant difference between the two techniques. Single operator USG-PIVC insertion was preferred as it reduced the need for additional clinicians [50]. Curtis and colleagues' [44] three-arm RCT reported no significant differences between USG-PIVC versus near-infrared imaging-PIVC and landmark insertion PIVC in a paediatric population of 418 patients.

The number of attempts to successful PIVC cannulation was also a measured in several studies [7,44,47,56,57,74]. Curtis and colleague's parallel RCT [44] reported a higher number of successful insertions in the second and third attempts between all three study arms (USG, near-infrared imaging landmark insertion), with the third attempt highest at 97.1 % compared to 70.6 % of first attempts. In contrast, Doniger et al., (2009) [7] found that the USG-PIVC group (n = 25) required significantly fewer attempts (median, 1; interquartile range [IQR], 1Y2.5; range, 1Y4) compared to SOC-PIVC group (n = 25) (median, 3; IQR, 2Y4; range, 1Y4).

Time taken to successfully cannulate was also recorded as a measure of success. Fourteen studies evaluated time required to cannulate using USG versus traditional landmark insertion [7,9–11,13,32,43,46,49,50,53,54,58,59]. Significant differences in time were identified between studies in using USG-PIVC, from approximately 1.2 mins minutes [13] up to approximately 27.6 min [58]. Overall USG-PIVC insertion was more time efficient than the traditional landmark insertion PIVC method of cannulation with the largest difference between USG and landmark insertion at 11.34 min [49]. Hart et al., also evaluated the time between single operator versus dual operator USG-PIVC insertion with single operator taking less time compared to dual operator by 25 s [50]. Erickson and colleagues, evaluated the median time between long-axis vs short-axis, identifying a one second difference between the two insertion techniques [46]. Overall time to PIVC placement may vary depending on the experience of the clinician and the number of successful insertions they had previously completed.

Six studies evaluated patient satisfaction of USG-PIVC compared to landmark insertion PIVC insertion, with all studies reporting a higher level of patient satisfaction among the USG-PIVC group [10,11,30,32,50,58]. In addition, where patient satisfaction was reported to be high, and cannulation successful, patients reported lower levels of pain during the procedure [19,29,54]. Smith (2019) reported that over 95 % of patients identified they preferred USG-PIVC to standard cannulation practice and would recommend USG-PIVC to a family member. In comparing USG-PIVC to standard practice, 79 % of patients believed USG-PIVC to be more effective and 52 % felt it was less painful [30].

4.4.3. The barriers and facilitators of education

The most common barrier identified in studies was the limited availability of ultrasound machines [27,28,39]. Other barriers identified included nurses' lack of ultrasound expertise [15], and inconsistency in knowledge and practice of educators responsible for training clinicians in USG-PIVC insertion [41]. Lastly, there were only four studies that formally evaluated the individual clinician pre and post training [17,41,45,48] and only one pilot study was reported [74].

4.4.4. Clinician competency assessment and pathways

While limited, competency and assessment pathways were assessed using pre-post evaluations, competency checklists, and supervision sign-off were based on the number of insertion attempts.

Only four studies formally evaluated clinicians USG-PIVC skills [17,45,48,74], using before and after surveys [17,45,48,74]. Duran-Gehring et al. assigned a pre-test to assess clinician's base-line knowledge [45]. Following an instructional video and skills laboratory in USG-PIVC insertions, clinicians were further evaluated via a post-test. Feinsmith and colleagues (2018), reported completing a pre- and post-test to assess USG knowledge, USG-PIVC indications, complications, and procedural steps training [48]. However, authors did not publish the results of these tests.

As a measure of success in training, Moore included a competency checklist consisting of 28-point marking criteria that identified the procedural steps involved in USG-PIVC insertion [17]. Once all criteria were met consistently, the clinician was able to perform the skill independently. Within the first year of the training, the total number of PIVCs attempted monthly increased and first attempt success rates reached a high of 98 % [17].

Ten studies examined the number of supervised USG-PIVC attempts required before a clinician was deemed competent [9,32,33,38–41,45,46,51]. Overall, the recommended number of successful attempts required to be deemed competent ranged between five to ten successful supervised cannulations.

There was a limited number of studies that included supervised practice insertion attempts on an inanimate gel model SIM (e.g. Blue Phantom ® by CAE Healthcare) prior to the clinician being deemed competent to practice in the clinical setting [9,32,33,38,74]. The number of supervised attempts varied from two practice attempts on a Blue Phantom model to 10 successful attempts supervised by an experienced clinician. In another study by Huang and colleagues, nursing proficiency performing an USG-PIVC insertion was assessed following a lecture and 45 min practice using a Blue phantom gel vascular model [51]. The nurses also logged their PIVC insertion attempts for review, over a two-month period. This was followed-up with a survey with the nurses at one month and one-year following the clinical skills education. [51].

4.4.5. Clinician confidence assessments and pathways

Ten studies that evaluated clinician confidence following USG-PIVC training, reported increased level of confidence post-training [15,27,28,30,39,44,51,57,59,60]. Archer-Jones et al.'s., study reported 12 % of clinicians felt more confident one month following a training session. This was an increase from 5 % of clinicians who initially felt confident or very confident using USG-PIVC prior to training [28]. Edward and Jones reported that 35.7 % of clinicians noted they "agreed," and 64.3 % "strongly agreed" in having confidence in their ability to obtain an USG-PIVC placement following training [39]. This increase in confidence following an education session using USG-PIVC by clinicians was also reported by Smith et al., 2019 [30]. Clinicians stated the course markedly increased their confidence and made them feel more likely to use USG-PIVC for difficult to cannulate patients in the future [30]. In another study, Erickson et al., found that following a didactic session with vessel visualization the nurses self-reported comfort level (using a 10-point Likert scale) was 6.5 (95 % CI = 4.8 – 8.2) and after the 10 attempts was 7.4 (95 % = 5.7 – 9.1) ($p = 0.02$) [59]. Conversely in Ng et al.'s., study, researchers found that only 6 % of the nurses agreed that they were comfortable using USG, with an additional 88 % responding that they 'somewhat agreed' that they were comfortable with using USG [60].

There was only one study included in the review that assessed clinician confidence using two different technologies, near infrared and USG, prior to commencing their training [44]. However, there was no follow up evaluation of confidence noted in the study following the training. Finally, Huang and colleagues also evaluated comfort using an USG to identify vessels and placing PIVCs pre- and post-training. On a scale out of 10, all participants went from a 2 out of 10 pre training to 3–4.5 out of 10 after one month and 4–5 out of 10 at one year following completion of training, all with a p value of < 0.001 [51].

5. Discussion

PIVC insertion is an important procedure in the ED. However, it can often be difficult for some patients, causing significant delays in diagnosis and treatment and discomfort. USG-PIVC offers a promising approach to increasing the success of intravenous cannulation, especially in patients with difficult vascular access. USG-PIVC has increased successful cannulation and reduced procedure time with less resources and increased patient satisfaction [9,11,32]. The results of this review confirm that there is benefit in educating a range of clinicians in using USG-PIVC. However, there continues to be a paucity of evidence regarding the most effective and sustainable teaching approach. Whilst the literature revealed a variety of teaching methods, they do not guarantee acquisition or retention of USG-PIVC knowledge and the best method for optimal application and retention remains unclear.

While current training programs have delivered successful USG-PIVC education to a range of clinicians with positive outcomes, there are many inconsistencies on how these programs are delivered and the variation of delivery to the different types of clinicians. The most common methods of delivery appear to be a combination of didactic and face to face and SIM sessions [6,7,10,15–17,19,27–29,33,35–45,48,51,53,56,58–61,74]. Didactic approaches reported similar topics including, vascular anatomy, ultrasound physics, vascular access techniques and ultrasound machine operation. However, some authors suggest clinical education is moving away from traditional didactic approaches to more practical approaches that include using technology to support knowledge and skills acquisition [62]. USG-PIVC insertion is a complex skill and teaching this to multi-disciplinary clinicians requires not only key clinical skills criteria to be taught but an up-to-date evidence-based method of delivery to be followed. This might involve using video podcasts to demonstrate the skill allowing students repetitive viewing in their own available time and in a suitable environment. This method of learning has shown to be successful in undergraduate education programs and would be beneficial in teaching USG-PIVC to ED clinicians [62]. Simulation-based training was used in over half of the training sessions [6,7,9,10,15–17,19,27–31,33,35–45,48,51,53,56,58–61,74]. These sessions varied in their training approach, but most covered the practical instruction on how to use the ultrasound equipment on a Blue phantom training model [9,39,41,74]. Practicing complex clinical skills in a simulation environment has been shown to increase clinician's self-efficacy and allows the learner to practice the skill multiple times [63]. This is essential for clinicians to form a belief in one's capabilities and to organise and execute actions required to manage prospective situations [64].

To ensure purposeful and meaningful learning, it is essential to use an effective pedagogical approach when delivering any clinical skills education. This is also the case when developing and delivering USG-PIVC education to the interdisciplinary ED workforce. To meet the needs of the adult learner, USG-PIVC education should be underpinned by an adult learning framework such as constructivism whereby learning is an active process in which learners construct new ideas or concepts based upon their previous knowledge [65], or experiential learning whereby learning is combined by experience, cognition and behaviour and is a continuous process grounded in experience [20,66–68]. Most studies reviewed did not formally identify any pedagogical approach or adult learning framework, however there was some evidence of this seen throughout the studies. This was evident in Costantino's study where ED physicians already familiar with ultrasound required less time training in learning USG-PIVC [11]. An understanding of different adult learning theories enables educators to select the most suitable instructional strategy, learning objectives, assessment, and evaluation approaches, based on the clinical context, and learning environment. Educators should then be able to combine learning theories, course content and clinicians understanding to improve their learning [69].

Effective learning strategies when delivering USG-PIVC education also requires rigorous evaluation. This review identified a lack of formal evaluation once education was completed. While three studies evaluated individual clinician competency following education via a pre and post-test approach, authors only reported PIVC competency of the total sample group and not of individual clinicians.

Compared to other clinical USG education programs, there is a paucity of assessment tools being used in USG-PIVC education [70,71]. However, attempts have been made to standardise observation-based assessment tools using task-specific checklists, global ratings scores, and objective structured assessment of technical skills [71,72]. For example, Schnobrich et al., modified the task-specific checklist survey tool measured three components of central line insertion: positioning, preparation, and central line placement [71]. This was beneficial in comparing different training models and evaluating student success in completing the checklist items and could be a valuable tool when teaching PIVC insertion techniques using USG. Having some form of consistent evaluation process would ensure a more robust education program overall.

When developing an effective education program, barriers and facilitators also need to be considered. In the studies reviewed it was reported that the availability of the ultrasound machine was a common barrier to educators' knowledge and practice of USG insertion techniques, and subsequent inability to deliver effective USG-PIVC education to clinicians as a result of this lack of expertise. Lack of essential equipment can impact clinician's ability to perform USG-PIVC insertion and therefore impact on their confidence. USG-PIVC skill mastery requires proficiency in acquiring and interpreting the image to identify the vessel and synthesising that interpretation into a clinical decision [72]. If there is lack of available US machines within a facility, educators will be unable to continually practice and master theses skills, inhibiting their mastery of the skills and reducing their ability to effectively educate other clinicians.

Educators within a health setting are usually competent practitioners in their clinical speciality. However, they may not have completed formal training in the concepts of education and pedagogy. This has results in the assumption that expertise in a clinical practice will translate into teaching proficiency [73]. Arguably these clinicians are generally very experienced using ultrasound for PIVC insertion but may not have the educational experience to formulate an USG-PIVC program that identifies adult learning concepts supported by relevant and up to date educational practices. Findings of this review indicate current educational approaches do not guarantee acquisition or retention of USG-PIVC skills. Methods required for optimal application and retention of USG-PIVC education remain unclear.

6. Implications for clinician education and research

An educationally informed and evidence-based USG-PIVC training program incorporating adult learning principles (e.g., constructivism or experiential learning) could have a significant impact on both clinician's skill development and retention of knowledge and improve clinical outcomes in vulnerable patient groups. As highlighted in this review, ED clinicians can quickly learn skills and apply them for successful USG-PIVC insertion. An USG-PIVC training program that includes a combination of short didactic sessions, along with simulation using inanimate vascular access arms would result in improved cannulation success rates, time to cannulation, and patient satisfaction.

It has the potential to, prevent avoidable patient harm by decreasing peripheral needle punctures and the need for CVCs. Additionally, the implementation of a successful USG-PIVC educational program could potentially translate across to other educational programs and practices within the healthcare setting.

7. Limitations

While integrative review is a valid approach when assessing educational practices, reliability is influenced by the quality of the included studies. USG-PIVC practices undertaken in ED were reviewed. However, the ED setting has a diverse range of clinicians performing PIVC insertions including, physicians, residents, fellows, nurses, corpsman and paramedics. Heterogeneity between included studies was therefore likely to give the variability PIVC placement methods and skills and clinical context. Additionally, as only studies published in English were included, some evidence may have been excluded.

8. Conclusion

There are a diverse range of ED clinicians who have been successfully trained to insert PIVCs with USG. A variety of educational methods, including didactic sessions, inanimate vascular access arm models and simulation, have resulted in improved cannulation success, time to cannulation and patient satisfaction. Barriers identified were associated with lack of ultrasound machines and variability in educational approaches in ED, therefore hindering effective PIVC insertion. To address these barriers, organisational support is needed to ensure ultrasound machines are available prior to development and implementation of training programs. Education programs based on the needs of learners and ED context, will ensure consistent practices are maintained and retained, leading to safer evidence-based practice.

Ethical approval

Not applicable.

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Declaration of Competing Interest

RMW reports investigator-initiated research grants provided to Griffith University from vascular access product manufacturer Becton Dickinson, unrelated to this project. NM reports investigator-initiated research grants and speaker fees provided to Griffith University from vascular access product manufacturers (Becton Dickinson, 3 M, Eloquest Healthcare and Cardinal Health); and a consultancy payment for expert advice from Becton Dickinson, unrelated to the current project. AJU reports investigator-initiated research grants and speaker fees provided to her former employer (Griffith University) from vascular access product manufacturers (Becton Dickinson, 3 M and Cardinal Health) unrelated to the current project.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.auec.2023.06.001.

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