

## Establishing the required components for training in ultrasound-guided peripheral intravenous cannulation: a systematic review of available evidence

Fredericus HJ van Loon<sup>1</sup>, Harm J Scholten<sup>2</sup>, Irene van Erp<sup>1</sup>, Arthur RA Bouwman<sup>3</sup>, Angelique TM Dierick-van Daele<sup>4</sup>

<sup>1</sup>Department of Technical and Anesthesia Nursing Sciences; Fontys University of Applied Sciences; Department of Anesthesiology, Pain Medicine and Intensive Care; <sup>2</sup>Department of Anesthesiology, Pain Medicine and Intensive Care, <sup>3</sup>Department of Signal Processing Systems and Electrical Engineering, TU/e University of Technology; Department of Anesthesiology, Pain Medicine and Intensive Care, <sup>4</sup>Department of People and Health Sciences; Fontys University of Applied Sciences; Department of Research and Education; Catharina Hospital, Eindhoven, The Netherlands

### Abstract

Ultrasound increases a first-attempt success rate for vascular access when considered by knowledgeable and experienced practitioners. Education and training of these practitioners in ultrasound-guided peripheral intravenous cannulation is becoming increasingly common, although no consensus has been reached regarding its curriculum. The current systematic literature review aims to explore different training modules and components in use, and its efficacy and efficiency in ultrasound-guided peripheral intravenous cannulation in hospitalized adults by different healthcare providers. Database search was performed from January 2009 to December 2018 for publications describing the training or education of healthcare professionals in ultrasound-guided peripheral intravenous cannulation in adult patients. Data-analyses was performed on 23 studies, concluding that competency on ultrasound-guided peripheral intravenous cannulation can be achieved after following a brief training in a fixed curriculum, consisting of a didactic training session, a simulated hands-on component, and is completed after a supervised live-case training. Lectures should focus on ultrasound physics, including the vascular anatomy. The hands-on training included identification of veins on a life model without cannulating, followed by cannulation of veins using a nonhuman tissue model. At the end, supervised cannulation of veins on the upper extremity with an ultrasound-guided technique was performed on live patients to show competency.

**Keywords:** catheterization; peripheral; vascular access devices; ultrasonography; education

### Introduction

Establishing peripheral intravenous access is a critical skill for patient care that can be technically challenging at times. Up to four out of five patients requires a periph-

eral intravenous catheter during their stay in the hospital, making peripheral intravenous cannulation the most frequently performed invasive medical procedure [1,2]. Nonetheless, despite its routine nature, peripheral intravenous cannulation is not always successful on the first attempt [3-6]. Using the traditional landmark approach, a success rate of 70% on the first attempt of peripheral intravenous cannulation was reported in a recently performed meta-analysis, whereas a success rate of 81% was seen in patients in which the ultrasound-guided technique was used as result of that study.

Over the past two decades, ultrasound has become widely accepted to guide safe and accurate insertion of

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Corresponding author: F.H.J. van Loon, MSc.

Catharina Hospital, Department of Anesthesiology, Pain Medicine and Intensive Care

Michelangelolaan 2,

5623 EJ Eindhoven, The Netherlands

E-mail: rick.v.loon@catharinaziekenhuis.nl

vascular devices in hospitalized patients. Improvements in technology, including miniaturization, have led to the development of pocket-size imaging devices. Ultrasound equipment has become more compact, with good image quality and less expensive, which has facilitated the growth of point-of-care ultrasonography [8]. Although there are many published studies demonstrating the benefits of ultrasound guidance for intravenous cannulation, simply placing an ultrasound probe on a patient's extremity does not ensure success [7]. The physical limitations of the behavior of ultrasound in tissue must be fully understood by the operator, otherwise failure of vascular cannulation will result [9].

To lower the threshold for applying ultrasound guidance during peripheral intravenous cannulation, different healthcare providers need to be trained and gain experience in using this technique [6,10,11]. Training and practice will subsequently improve ultrasound use and increase success, at which success using ultrasound for intravenous cannulation is based on appropriate equipment and preparation, optimal vein selection, and effectively using ultrasound to understand and guide needle tip position [8]. Ultrasound physics and transducer properties should be part of the training for understanding ultrasound-related artefacts and pitfalls, as concluded in a previous study by Van Loon et al [6]. Education surrounding the insertion of peripheral intravenous catheters remains undefined because a standardized program for trainees, nor a guideline for supervisors, is lacking in current practice [11]. Understanding and establishing the level of training required for safe insertion procedures and management of ultrasound-guided peripheral intravenous cannulation is therefore the focus of this study [11].

Education and training of practitioners, both physicians and nurses, in ultrasound-guided peripheral intravenous cannulation is becoming increasingly common and key management of the difficult-access patient; however, no consensus has been reached regarding its value [8,11,12]. Challenges include gaining better understanding of when and how point-of-care ultrasound can be used effectively, and structuring policy and reimbursement to encourage appropriate and effective use [7]. Therefore, the current systematic literature review aims to explore different training modules and components in use, and its efficacy and efficiency on ultrasound-guided peripheral intravenous cannulation in hospitalized adults by different healthcare providers.

## Materials and methods

This systematic literature review was conducted following the established guidelines from the Preferred Re-

porting Items for Systematic Reviews and Meta-Analyses (PRISMA) [6,13].

### *Search strategy*

Observational and interventional studies describing training or education of healthcare professionals in ultrasound-guided peripheral intravenous cannulation in adults were systematically searched in databases of peer reviewed literature, including PubMed, Clinical Key, Cochrane Library of Clinical Trials, and Trip Database. Manuscripts in the English and Dutch languages as published from January 1, 2009 until December 31, 2018 were included. The early used portable ultrasound machines were hampered by poor image quality, but imaging quality and employability increased from 2010 [8]. For this reason, only studies published in the last ten years were included. Google Scholar was searched for additional literature sources. The primary search criteria included "peripheral intravenous cannulation, peripheral intravenous access, peripheral intravenous catheterization", and were connected by the Boolean "AND" with the terms "ultrasound, ultrasound guidance, ultrasonography, ultrasound-guided", and connected by "AND" to "learning curve, education, training". Medical Subject Headings (MeSH) terms was used if appropriate.

### *Study selection*

Studies describing the content or components of the training program, as well as studies describing the learning curve of healthcare professionals for ultrasound-guided peripheral intravenous cannulation in adult humans, were included. Studies were excluded for the following reasons: (1) intravenous cannulation on other sites of the body (e.g. central venous) rather than the upper extremity; (2) intravenous insertion of other devices (e.g. central venous catheters, peripheral inserted central venous catheters, dialysis catheters, arterial catheters) rather than short peripheral intravenous catheters; (3) describing the deployment of the ultrasound-guided technique without focusing on the training or learning curve; and (4) if a non-ultrasound-guided technique was used (e.g. traditional approach based on landmarks) [6]. Studies were selected regardless the setting in which the study was performed (e.g. emergency department, surgical operating theatre complex), the applied ultrasound technique (e.g. single- or two-operator, short- or long-axis viewing, dynamic or static technique), or the practitioner included in the study (e.g. nurse or physician).

### *Outcome measures*

This study focuses on the following outcome measures: elements or content of the training or educational program, as well as the length or duration, covered topics, used materials, preconditions, homework or foreknowledge, the learning curve or punctures needed until

a stable success rate was reached, final objectives, and certification. This study does not concentrate on the final implementation of an ultrasound-training program in daily practice or educational curricula.

**Data extraction**

Two reviewers (F.L. and I.E.) screened eligible studies independently, according to a previous presented strategy on title and abstract, and classified them as being relevant, potentially relevant, or not relevant [6]. Secondly, full-text of the articles that were classified as being relevant were analyzed by both reviewers independently [6]. Hereafter, both reviewers decided individually if the study was eligible or not, based on the inclusion and exclusion criteria [6]. Any discrepancy between the reviewers was resolved with a final decision from a third independent investigator (A.B.) [6]. Eligibility of studies classified as being potentially relevant in the first phase was also decided by an independent investigator (A.B.), after which those studies with a positive final decision were included [6].

**Statistical analyses**

Ad-hoc tables will be designed to summarize data from the included studies and show their key characteristics and important questions related to the objectives of this review. After data extraction, reviewers will determine whether a meta-analysis is possible.

**Results**

In total, 23 studies were selected and included for final analysis after database review, removal of duplicates, title and abstract screening, and full-text review (fig 1), of which the characteristics are represented in Table I.

The presentation of the results is subdivided into several main topics that are considered relevant for answering the literature search question or supporting the conclusion. In general, training for ultrasound-guided peripheral intravenous cannulation can be divided into a didactic training module, a hands-on training session, and training of skills in life-cases. An overview is given in figure 2.

**Didactic training**

In the didactic training session, lectures are used to support the transfer of knowledge [14]. The didactic training session can be divided mainly into three general themes: ultrasound physics; the ultrasound-guided technique of cannulation; and the vascular anatomy. Within ultrasound physics, subjects such as: basic ultrasound use; the ultrasound probe and probe selection; and the ultrasound machine and knobology of the device, are explained [10,14-24]. Trainees in ultrasound techniques focused on: differentiating veins from arteries, nerves

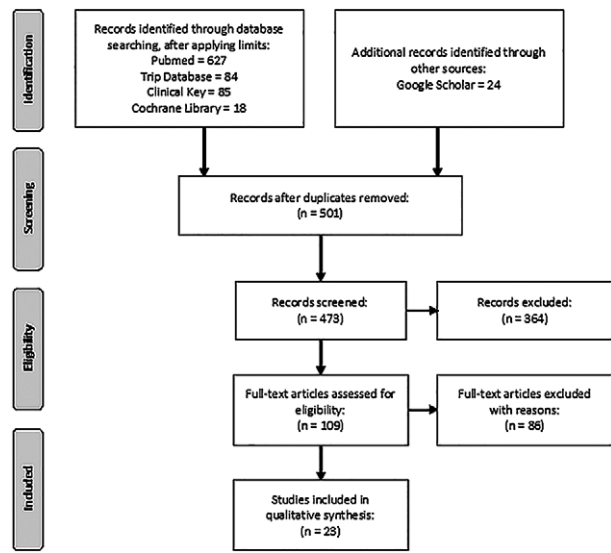


Fig 1. PRISMA flowchart of study selection

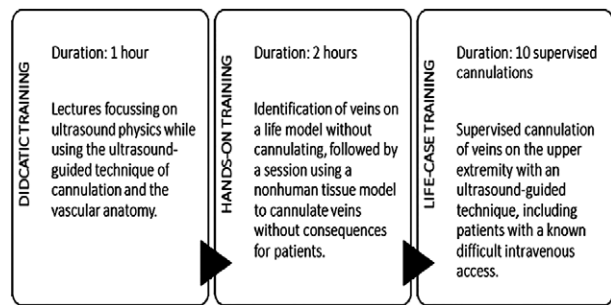


Fig 2. Overview of training sessions, including the components and content, and suggested duration of the sessions.

and muscles; applying venous compression or (color) Doppler to identify venous structures; appropriate selection of the cannulation site, vein and needle entry point; the approach of visualizing the needle or the guidance technique (dynamic short-axis out-of-plane or dynamic long-axis in-plane); and optimization of images, acquisition and screen settings (gain and depth) [10,14,15,17-26]. Theoretical considerations of the anatomy include the vascular anatomy of the upper extremity and physiology of the circulation [10,14,15,18,20,21,27]. Besides these three main topics, didactic training covers subjects as disinfection and catheter care, prevention of infections, disinfection and cleaning of the machine, and care of equipment [14,18,20,24]. Also, the procedure of peripheral intravenous cannulation, documentation, indications for ultrasound use, and identification and management of complications are included in training programs [10,14,15,17,19,22,28]. Some studies included a video demonstration of peripheral intravenous cannulation under ultrasound guidance as part of the training program

Table I. Study information

Author (year)	Study setting or design	Practitioners or department	Design of the training	Outcome or main result
Adhikari (2015) [34]	Cross-sectional study	Emergency department nurses with no prior experience in ultrasound-guided cannulation, in the emergency department	Didactic, hands-on (non-human tissue model), followed by a questionnaire, ultrasound-technique not specified	subjects successfully demonstrated competency during the training session, nurses had a high level of comfort using ultrasound for vascular access
Ault (2015) [16]	Not specified	Registered nurses with no prior experience in ultrasound-guided cannulation, department not specified	Didactic, hands-on (non-human tissue model), training on live cases, ultrasound-technique not specified	Training of registered nurses resulted in proficiency and competency in the ultrasound-guided technique
Bahl (2016) [30]	Prospective non-blinded randomized controlled trial	Emergency department nurses with no prior experience in ultrasound-guided cannulation, in the emergency department	Didactic, hands-on, ultrasound-technique not specified	Success rate of peripheral intravenous cannulation increased after training of nurses in applying ultrasound guidance
Bauman (2009) [32]	Two-phase prospective systematically allocated non-blinded cohort study	Emergency department technicians with no prior experience in ultrasound-guided cannulation, in the emergency department	Didactic, hands-on (non-human tissue model), with the one-person short-axis technique	A brief training program in ultrasound guidance resulted in improved speed, less skin punctures and greater patient satisfaction than traditional approached in patients with difficult intravenous access
Carter (2015) [33]	Single centre, non-blinded quasi-randomized study	Emergency department nurses, in the emergency department	Hands-on (non-human tissue model), ultrasound-technique not specified	No difference was observed between nurses and residents on success rate of ultrasound-guided intravenous cannulation
Dargin (2010) [26]	Prospective observational study	Emergency medicine residents with no prior experience in ultrasound-guided cannulation, in the emergency department	Didactic, hands-on, ultrasound-technique not specified	Ultrasound-guided peripheral intravenous catheters had a higher premature failure rate in patients with a difficult intravenous access
Davis (2017) [36]	Not specified	Medical students, department not specified	Didactic, hands-on (non-human tissue model), ultrasound-technique not specified	After training, medical students showed no differences in success using either a smaller or a larger vessel phantom
Duran-Gehring (2016) [17]	Retrospective study	Emergency department technicians, in the emergency department	training and ultrasound-technique not specified	Training of emergency department technicians resulted in competency in the ultrasound-guided technique
Edwards (2018) [15]	Quality improvement project	Emergency department nurses with no prior experience in ultrasound-guided cannulation, in the emergency department	Didactic, hands-on (non-human tissue model), with the one-person short-axis and long-axis technique, both dynamic and static technique	Training of emergency department nurses resulted in competency in the ultrasound-guided technique
Feinmith (2018) [18]	Quality improvement project, prospective single-arm pre- and post-study	Emergency department nurses with no prior experience in ultrasound-guided cannulation, in the emergency department	Pretest, didactic, hands-on (non-human tissue model and on classmates), posttest, training on live cases, ultrasound-technique not specified	Training of emergency department nurses resulted in competency in the ultrasound-guided technique
Keleekai (2016) [29]	Randomized, wait-list control group study, with crossover design	Registered nurses, in the postsurgical units and medical/surgical orthopaedic unit	Self-paced interactive online education, hands-on (non-human tissue model), ultrasound-technique not specified	Improvements in nurses' knowledge, confidence, and skills with the use of a simulation-based blended learning program

Lian (2017) [37]	Not specified	Medical students, department not specified	Hands-on (non-human tissue model), ultrasound-technique not specified	Traditional face-to-face teaching on ultrasound-guidance resulted in higher success rates than those not receiving education
Miles (2012) [28]	Not specified	Emergency department nurses with no prior experience in ultrasound-guided cannulation, in the emergency department	Didactic, hands-on (non-human tissue model), with the one-person short-axis and long-axis technique	Ultrasound-guided peripheral intravenous cannulation resulted in increased patient satisfaction, decreased nurse/physician frustration, cost and time savings, decreased complications related to central line placement
Moore (2013) [35]	Not specified	Emergency department nurses, in the emergency department	Didactic, hands-on, training on live cases, ultrasound-technique not specified	Training of emergency department nurses resulted in competency in the ultrasound-guided technique
Oliveira (2016) [19]	Not specified	Emergency department physicians, emergency department nurses and corps men, in the emergency department	Didactic, hands-on (non-human tissue model and on classmates), training on live cases, with the one-person short-axis and long-axis technique	Training of emergency department nurses resulted in competency in the ultrasound-guided technique. Developing a training program is feasible and safe
Owens (2016) [20]	Retrospective study	Registered nurses, department not specified	Didactic, hands-on (non-human tissue model), training on live cases, ultrasound-technique not specified	No statistical increase in ultrasound-guided intravenous catheter placement per nurse by including proctored ultrasound-guided cannulation to receive continues educational unit credit
Partovi-Deilami (2016) [10]	Non-randomized pre- and post-study	Nurse anaesthetists, in the surgical theatre complex	Didactic, hands-on (non-human tissue model and on classmates), training on live cases, ultrasound-technique not specified	Ultrasound guidance resulted in improved speed, increased success rate with less skin punctures, increased quality of care, but no change in satisfaction
Schoenfeld (2011) [21]	Prospective, observational study	Emergency department technicians, in the emergency department	Didactic, hands-on (non-human tissue model and on classmates), training on live cases, with the one-person short-axis and long-axis technique	Training of emergency department technicians resulted in competency in the ultrasound-guided technique
Shokoohi (2013) [22]	Time-series analyses	Emergency medicine residents and emergency department technicians, in the emergency department	Didactic, hands-on (non-human tissue model), training on live cases, ultrasound-technique not specified	Training in ultrasound guidance resulted in reduces placement of central venous catheters, especially in critical ill patients
Stolz (2016) [23]	Prospective, observational study	Emergency department nurses and paramedics, in the emergency department	Didactic, hands-on (non-human tissue model), training on live cases, with the long-axis technique	Ultrasound guidance resulted in increased success rate
Vitto (2016) [27]	Randomized crossover study	Medical students, in the skill laboratory	Didactic, hands-on (non-human tissue model), ultrasound-technique not specified	Training resulted in competency in the ultrasound-guided technique
Weiner (2013) [24]	Prospective, multicentre pilot study	Emergency department nurses, in the emergency department	Didactic, hands-on (non-human tissue model), training on live cases, with the one-person technique	Training of emergency department nurses resulted in a decreased need for physicians
White (2010) [25]	Not specified	Emergency department nurses, in the emergency department	Didactic, hands-on (non-human tissue model and on classmates), training on live cases, with the one-person short-axis and long-axis technique	Training of emergency department nurses resulted in competency in the ultrasound-guided technique. Developing a training program is feasible and safe



[14,16,18,29,30]. The training session as described in the study by Keleekai et al consisted of an online course, including several aforementioned aspects [29].

#### ***Hands-on training***

A hands-on training session logically follows the didactic training, requiring trainees to gain and show competency before acting on life cases [15]. A hands-on training session in a simulation setting creates a situation in which trainees can familiarize themselves with the ultrasound machine and equipment [10,14,24,29]. Furthermore, it enables trainees to focus on basic ultrasound acquisition and creating still images, as well as becoming aware of the upper extremity anatomy [10,14,20,22,24,29,31,32]. Identifying the anatomy of the upper extremity by tracing veins on a life model without cannulating it allows trainees to appreciate the vein characteristics, and gain eye-hand coordination with probe manipulation [10,14,18-22]. A 1:1 hands-on session using a nonhuman tissue model, to continue, creates a possibility for trainees in emphasizing confirmation and visualizing of the needle tip while deforming the target vein prior to cannulation, the dexterity to insert an intravenous catheter while holding the probe and watching the screen (eye-hand coordination), and visualization of venous cannulation on the ultrasound screen in real-time [10,14-19,21-26,28,31,32]. A simulated training session could also focus on sterility and aseptic techniques without consequences for the patient [24,27]. According to Adhikari et al practitioners had a high level of comfort using ultrasound for intravenous cannulation after a focused simulation training session, resulting in the accurate identification of the vascular anatomy and performing ultrasound-guided vascular access [34].

#### ***Life-case training***

During life-case training, trainees gain experience and routine in cannulating veins on the upper extremity with an ultrasound-guided technique in human subjects, including patients with a known difficult intravenous access [14,15,23,29,31]. Focus of the trainee should be on keeping the needle tip in the ultrasound field while navigating to the vein, perfecting probe control, treading the needle under ultrasound guidance, and attempting cannulation of smaller and deeper veins [24]. According to the statement of Edwards et al the biggest question on determining competency was how many supervised successful procedures needed to be performed before a trainee could function independently [15]. Of the included studies, most recommend 10 supervised attempts in life cases [15,17,24,27,29]. Oliveira et al and Partovi-Deilami et al found 3 supervised cannulations to be sufficient to show competency, while Duran-Gehring et al and Edwards et al suggest trainees to perform 5 supervised

attempts in their training program [10,15,17,19]. Additionally, trainees should perform 5 attempts under indirect supervision, with oversight immediately available, according to Edwards et al [15]. However, the study by Moore et al required 25 supervised attempts to produce a success rate of 80%. Stolz et al described in their study that supervision and training must be continued until a trainee reached an individual success rate of 70% on the first attempt, and for this, 4 supervised attempts were needed [23].

#### ***Additional provisions***

Keeping a log or data collection form can provide support in demonstrating competency, in which the formulated final objective can be leading [16-18,34]. Competency can be determined with testing of the practitioners before and after the training [16,17,20]. Duration of training varied between the included studies, from two hours until multiple days [10,17,22,23,34]. Didactic session duration ranged between 30 minutes up to 3 hours [10,14,15,18,20,24-27,29,34]. The same applied to hands-on training, with the duration of the training varying between 1 and 2 hours [10,15,18,24,25,27,31]. Edwards et al, in the meantime, placed no restrictions on the time needed for the hands-on training, while Keleekai et al described a hands-on training with a duration of 8 hours [15,29].

#### ***Effects of training***

As concluded by Lian et al, trainees receiving education on ultrasound-guided venous cannulation performed significantly better than those not receiving education [35,37]. Trainees with no prior ultrasound experience can achieve competency on ultrasound-guided peripheral intravenous cannulation when given a dedicated training and closed supervision in a fixed curriculum [10,14-20,22-24,26,28,29,31]. After completing a brief training program, participants were more successful in obtaining intravenous access using ultrasound guidance in patients with a known difficult venous access when compared to a situation in which the traditional landmark technique of peripheral intravenous cannulation was used [19,23,29,31].

#### ***Assumptions for implementation***

Several administrative processes need to be defined and implemented before the implementation of a training program, including the development of a practice statement, procedure guidelines, operational plan, and competency validation [14]. To add to this, an environment with widespread opportunities for ultrasound-guided peripheral intravenous cannulation is recommended for the rapid acquisition of skills [17]. As the number of ultrasound machines in clinical areas increases, it is important that education programs to support their safe and

appropriate use are developed [36]. First attempt success logically increases after time and practice [17,27].

### Discussions

In this systematic review, we focused on different training modules and components in use for ultrasound-guided peripheral intravenous cannulation in hospitalized adults, and determined that an optimal training session includes a didactic training session, followed by a hands-on session in a simulated environment, and is completed after a life-case training. The didactic session should cover topics as basic ultrasound physics, ultrasound-guided techniques of cannulation, and the upper extremity anatomy. The following 1:1 hands-on training session should focus on familiarization with ultrasound equipment and techniques using a nonhuman tissue model or on a life model without cannulating. A final life-case training gives participants the opportunity to gain experience and routine in cannulating veins on the upper extremity with an ultrasound-guided technique, under direct supervision, in live patients. Competency in ultrasound-guided peripheral intravenous cannulation can be achieved after following a dedicated training and closed supervision in a fixed curriculum, in which different steps regarding the procedure should consecutively be addressed, which could be a guidebook for the training of this procedure of ultrasound-guided peripheral intravenous cannulation.

According to the practice guideline for the use of ultrasound to guide vascular access procedures of the American Institute of Ultrasound in Medicine, training should include principles and practice of ultrasound, instruction in the techniques of ultrasound guidance for vascular access, and assessment of competency in a simulated or actual patient care setting [8,37]. In agreement with Ault et al competency can be defined as: being able to select the correct ultrasound probe; to set the correct depth, gain and target vein; properly positioning the target vein in the center of the ultrasound screen; correctly aligning the catheter tip in the middle of the probe over the target vein; tracking the catheter tip through the skin and tissue to the vein wall, including indenting the vein under ultrasound guidance before cannulating it; and cannulating the vein successful and achieving a bulls-eye image [16].

A combination of approaches of education to assist practitioners involved in the training for ultrasound-guided intravenous cannulation, increases the likelihood of transition of the procedure into practice [38]. Trainees became more competent when face-to-face and online learning were combined, which created the challenge of finding innovative ways to teach clinical skills [39]. Simulation-based training is one of the strategies used to

improve quality in healthcare. The effect of simulation-based training for nurses seems to be positive in improving nurses' skills, whereas computer-based simulation is stated to be the most effective strategy on nurses' knowledge. Virtual reality training environments are used when training in reality is challenging because of the high costs, danger, time or effort involved, or when practicing on life cases is not possible due to ethical reasons [40]. Screen-based virtual reality simulators or virtual worlds are the most frequently used systems, and seem to be usable by a variety of end users, regardless of computer or gaming experience [41,42]. In the end, preparing trainees to bring their expertise to improve new processes requires learner activation [43].

Being a relatively new procedure, there is a limited amount of evidence to guide best training practices when teaching ultrasound-guided peripheral intravenous catheter insertion to novices. The practitioner responsible for ultrasound-guided intravenous access may vary based on the institution and the vein to be accessed, but may include technicians, nurses, advanced practice clinicians, and physicians [44]. Ultrasound-guided intravenous cannulation is an assessable procedure, because it is relatively easy to learn and could be provided at bed side [7,45-48]. Aside from the supplies necessary for vascular access, an ultrasound machine with a high-frequency capable probe is all that is necessary [44]. First attempt peripheral intravenous cannulation success would, however, be improved if practitioners with greater procedural experience and an increased perception of the likelihood of success performs the cannulation. [49]. The use of ultrasound should be considered early if peripheral venous cannulation proves to be difficult [50]. Nonetheless, patient-related factors, ultrasound physics and transducer properties should be part of the training for understanding of ultrasound related artefacts and pitfalls [2,5,51].

Selecting an appropriate vein to cannulate by scanning the upper extremity with the ultrasound probe after applying vasodilation is an important part of the procedure of ultrasound-guided peripheral intravenous cannulation [52]. Therefore, practitioners should have knowledge of upper extremity vascular anatomy before cannulating a vein and to distinguish veins from other structures [10,14,15,19,21,22,27,52]. Setting the correct gain and depth assists in creating an appropriate presentation of the target vein on the screen: knowledge of knobology of the ultrasound machine is required [22,52]. Knobology can be translated as the functionality of controls on an instrument as relevant to their application [53]. Becoming familiar with the machine and the controls used for image generation optimizes the scans being performed and enhances the use of ultrasound in patient

care, although new-developed ultrasound machines automatically optimizes screen settings [53]. In addition, training should focus on hand-eye coordination, which is denoted as being the most difficult aspect of utilizing ultrasound [54]. Hand-eye coordination is necessary to hold the probe in one hand and cannulate the vessel with the other, but a lack in this practice can nullify any time saved during the procedure [55].

### **Limitations**

A systematic review provides an objective overview of available evidence. Despite this, a number of challenges has to be taken into account when including qualitative studies. Data in qualitative research often comes from different sources, resulting in large quantities of raw material to be analyzed that must be systematically dissected, rearranged, organized and interpreted in order to answer the research questions [56]. Due to the inclusion of qualitative data sources, a quantitative data analysis with pooling of results was not possible [56,57]. Except for a lack of quantitative analyses, there were differences between the included studies themselves. Studies were carried out in different healthcare settings, including the emergency department, skills laboratory, postsurgical and medical units, and the surgical theatre complex. Moreover, various types of practitioners participated in the included studies, including emergency department nurses, technicians and physicians, registered nurses, nurse anesthetists, and medical students, with a different level of experience and knowledge. As with most invasive procedures, there is operator variability in skills and results, which possibly caused heterogeneity among the studies [52,57]. The effect of heterogeneity could be enhanced by the different approaches of ultrasound guidance that were applied throughout the studies, including the short- and long-axis approach, as each approach has its advantage, but also its limitations. In addition to the discussion on the most optimal approach, differences in training settings could have resulted in different outcomes. Neither identification of patients at high risk nor the definition of a difficult intravenous access was equal between the studies included. Finally, there may be publication bias in this systematic literature review, although the likelihood of publication bias was minimized by performing an extensive literature search for published and unpublished articles [57,58].

### **Further research**

Although ultrasound machine size and equipment have evolved, the basic principles and fundamental functions have remained essentially the same. There is currently no consensus on the number of attempts that is required to determine competency, ranging from 5 to 25 attempts throughout the included studies [16,24,27,34,35,52,59].

Neither was there consensus on the definition of competency, resulting in the need for more data to determine the number of ultrasound-guided cannulations to become competent in this modality [52]. Larger studies, with an increased level of evidence, should decide which training curriculum results in highly skilled practitioners in ultrasound-guided peripheral intravenous cannulation. To add to this, differences between healthcare providers, as well as their different levels of experience and knowledge, should be part of this studies. While various training courses exist, most are focused on how to improve the visibility of peripheral veins on phantoms or in healthy volunteers. These enhanced simulation training should focus on pitfalls related to visualization by ultrasound, avoidance of applying excessive pressure on the tissue, and appropriate techniques to improve venous conditions and making them suitable for cannulation. Improved simulation training with a focus on needle manipulation and cannulation, that is adequately supported by evidence, could enhance the safety and efficacy of ultrasound-guided peripheral intravenous cannulation in hospitalized patients.

### **Conclusions**

Training in and knowledge of ultrasound physics are important issues before applying ultrasound-guided procedures. Ultrasound physics and transducer properties introduce limitations with respect to beam width and elevation plane, that are especially important in case of small targets, such as peripheral vessels. Competency on ultrasound-guided peripheral intravenous cannulation can be achieved after following a brief training in a fixed curriculum. This study suggests evidence-based recommendations that provide directions for establishing consistency in the development of training programs and measuring competency through completion of a didactic training session, followed by a hands-on session in a simulated environment, and is completed after a supervised life-case training. More research is necessary to establish stronger recommendations and clearer directives.

**Conflict of interest:** none

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