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Review

Ultrasound-guided peripheral intravenous canulation by emergency nurses: A systematic review and *meta*-analysis

Lorena Álvarez-Morales [a], José L. Gómez-Urquiza [b,*], Nora Suleiman-Martos [a], María José Membrive-Jiménez [a], Ana González-Díaz [b], Raquel García Pérez [a], Antonio Liñán-Gonzalez [c]

[a] Faculty of Health Sciences, University of Granada, 18016, Conocimiento Avenue, Granada, Spain
[b] Ceuta Faculty of Health Sciences, University of Granada, Cortadura del Valle s/n, 51001 Ceuta, Spain
[c] Melilla Faculty of Health Sciences, University of Granada, Santader St., 52005 Melilla, Spain

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ABSTRACT

Background: Peripheral intravenous cannulation is a common procedure in the emergency department. Nevertheless, failure rates during the first attempt are as high as 40% in adults and 65% in children. Evidence suggests that physician performed ultrasound-guided peripheral intravenous cannulation (USG-PIVC) is an effective alternative to the traditional method; however, there is insufficient data on the efficacy of the technique performed by nurses.

Objective: To examine the efficacy of the USG-PIVC technique performed by emergency department nurses.

Methods: A literature review with *meta*-analysis was performed. The databases used were PubMed, Scopus and CINAHL. The search was conducted in March 2023. Two *meta*-analysis one of clinical trials about the effectiveness and one about the succession rate were performed.

Results: 20 studies were selected and analysed. The studies showed that USGPIVC performed by emergency nurses increased the probability of both the overall success and a successful first attempt compared to the standard technique. In addition, patients showed high satisfaction and lower complication rates. However, the procedure had no significant effect on the time or number of attempts required. A lower probability of success was obtained as regards peripheral intravenous cannulation when the standard technique was used, OR = 0.42 (95 %CI 0.25–0.70p < 0,05).

Conclusions: Ultrasound-guided peripheral intravenous cannulation performed by emergency nurses is a safe and effective technique.

1. Introduction

Every year billions of peripheral intravenous catheters (PIVC) are cannulised internationally [1] and almost 60 % of patients require at least one peripheral intravenous line during their admission [2], with 76.57 % of patients admitted to hospital in 2021 carrying a PIVC according to the Study on the Prevalence of Nosocomial Infections in Spain [3]. Intravenous access is the line of choice in the hospital emergency department due to its rapid action and efficacy [4,5], with a prevalence of 90 % usage in emergency departments Rodríguez-Calero et al., 2020 [cited 11 April 2023,; Salvetti et al., 2021 [cited 11 April 2023];17 [6–7].. Even though the cannulation of a PIVC is one of the most common hospital procedures, the technique is not always easy or successful, with some studies reporting 40 % of failures in the first cannulation attempt of a PIVC in adults and up to 65 % in children [8].

Difficulties in PIVC cannulation increase the number of punctures and, therefore, associated complications, pain, dissatisfaction in the patient, delay in diagnosis, at the start of intravenous treatment, as well as an increase in the use of more invasive devices such as central intravenous catheters [6,9,10]. Furthermore, the difficulty in obtaining peripheral intravenous access entails a higher healthcare cost, due to the employment of material resources, the increase in the time the professional dedicates to the technique, and the greater number of nurses necessary to successfully achieve the peripheral intravenous line [11].

The are different potential risk factors associated with difficult intravenous access but, among others, most authors point to a relationship between diabetes, vascular disease, cancer and chemotherapy treatment and the presence of difficult intravenous access [12].

* Corresponding author.
E-mail address: jlgurquiza@ugr.es (J.L. Gómez-Urquiza).

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Furthermore, a blood vessel diameter under 3 mm, lack of visibility and palpability following the application of the tourniquet are also associated with increased cannulation difficulty [12].

There is no agreed universal definition of a patient with difficult intravenous access. However, Rodríguez-Calero et al. [6], proposed that patients that meet the following criteria meet the conditions for difficult intravenous access: two or more failed cannulation attempts; the need to use support techniques (ultrasound, infrared or transillumination); impossibility of visualisation or palpation of intravenous access points; the need for cannulation of a central line following the impossibility of obtaining peripheral access, and abandonment of the procedure due to lack of success. Some scales are currently available in the literature for identifying patients with difficult intravenous access, which are useful instruments for helping healthcare professionals in their clinical practice. Examples are the "difficult intravenous access score" [13] as a tool for identifying paediatric patients with difficult intravenous access, which was validated and refined three years later [14], and the Adult Difficult IntraVenous Access scale [15,16] to determine the risk in adults, specifically in surgical patients. Nevertheless, none of the mentioned instruments have been specifically created to be used in the emergency department. With the aim of providing a response to this need, Salleras-Duran L et al. [17] developed the Adult Difficult Venous Catheterization (A-DICAVE) scale, which involves a quick and easy-to-use system to predict the presence of difficult intravenous access in emergency department patients based on three variables: vein visibility; vein palpability and known history of difficult intravenous access.

The use of these scales permits the early detection of the patient with difficult intravenous access and facilitates decision-making for using support devices for the identification and visualisation of peripheral veins [17]. Amongst these techniques are ultrasound, transillumination and infrared light-guided peripheral intravenous cannulation, with the first being the most utilised. The ultrasound scan consists in the registration of echoes or reflections of high frequency sound waves aimed at the tissue, which permits the visualisation of organs and internal structures [18]. Ultrasounds are used to diagnose and explore body structures in many health specialities and, as it is a non-invasive, non-painful and inexpensive technique, its use allows nurses to visualize veins before inserting a peripheral venous catheter or equivalent [18]. Ultrasound-guided cannulation is defined as the exploration by ultrasound carried out with the aim of verifying the position of a blood vessel prior to puncturing the skin, followed by the obtaining of real time images to guide the needle during the entire cannulation procedure [19].

The last few decades have seen the employment of the ultrasound scanner for the cannulation of central venous lines in clinical practice, due to the high amount of evidence that points to it being a technique with a high success rate and low risk [20].

Even though ultrasound involves a consolidated procedure of central venous lines, the same does not occur in the case of peripheral access. Current evidence suggests that the ultrasound-guided peripheral intravenous catheter (USG-PIVC) cannulation technique is an effective alternative to the traditional method (via palpation, visualisation or anatomical references) in patients with difficult intravenous access, reflected in an increase in first puncture success and a reduction of associated complications Xiong et al., 2021 [cited 11 April 2023,; Berlanga-Macías et al., 2022 [cited 11 April 2023];21 [21–22]:307.

Along this same line, the International Congress on Vascular Access recommends the training of nurses in ultrasound guided PIVC cannulation [23]. However, despite the solid consolidation of the efficacy of the ultrasound-guided peripheral intravenous cannulation technique carried out by nurses or physicians [24], insufficient data reviews exists on the procedure carried out independently by emergency nurses. Thus, it is important, due to the different characteristics of time and patients in emergency units compared with other areas, to analyze the effects of ultrasound guided PIVC cannulation in emergency nurses.

Therefore, the purpose of this systematic review is to examine the efficacy of the ultrasound-guided peripheral intravenous cannulation technique carried out by emergency department nurses.

2. Methodology

2.1. Design

A systematic review with *meta*-analysis was carried out, a scientific study characterised by identifying and summarising existing knowledge on a specific research topic [25]. In order to formulate the research question the PICO format was followed (P: emergency department nurses; I: ultrasound-guided peripheral intravenous cannulation; C: traditional technique; O: clinical and technique performance variables).

The research question was defined as: what are the clinical and technical performance results of using ultrasound-guided peripheral intravenous cannulation by emergency nurses? Are the results better than using the traditional technique?

2.2. Search strategy

The studies were identified via a bibliographical search in three databases: PubMed, Scopus and CINAHL, which was carried out on 23 March 2023.

The search employed MeSH and DeCS terms, and the strategies were personalised for each database due to the variability of search interfaces (Table 1).

Table 1
Search strategy with Boolean operators in the databases.

PubMed	(("Catheterization, Peripheral"[MeSH Terms] OR "Peripheral venous cannul*"[Title/Abstract] OR "Peripheral intravenous cannul*"[Title/Abstract] OR "Peripheral vascular cannul*"[Title/Abstract] OR "peripheral line"[Title/Abstract] OR "peripheral intravenous line"[Title/Abstract] OR "peripheral venous line"[Title/Abstract] OR "peripheral intravenous catheter*"[Title/Abstract] OR "Peripheral venous catheter*"[Title/Abstract] OR "peripheral vascular catheter*"[Title/Abstract] OR "peripheral vascular access"[Title/Abstract] OR "peripheral IV access"[Title/Abstract] OR "peripheral venous access"[Title/Abstract] OR "peripheral intravenous access"[Title/Abstract]) AND ("Ultrasonography "[MeSH Terms] OR "Ultrasonography, Interventional"[MeSH Terms] OR "Ultrasound"[Title/Abstract] OR "ultrasound guid*"[Title/Abstract] OR "ultrasonography"[Title/Abstract] OR "sonography"[Title/Abstract]) AND ("Emergency Service, Hospital"[MeSH Terms] OR "emergency department"[Title/Abstract] OR "emergency service"[Title/Abstract] OR "emergency nursing"[MeSH Terms]) AND ("nurs*"[Title/Abstract]))
Scopus	TITLE-ABS-KEY (("Catheterization, Peripheral" OR "Peripheral venous cannul*" OR "Peripheral intravenous cannul*" OR "Peripheral vascular cannul*" OR "peripheral line" OR "peripheral intravenous line" OR "peripheral venous line" OR "peripheral intravenous catheter*" OR "Peripheral venous catheter*" OR "peripheral vascular catheter*" OR "peripheral vascular access" OR "peripheral IV access" OR "peripheral venous access" OR "peripheral intravenous access") AND ("Ultrasonography " OR "Ultrasonography, Interventional" OR "Ultrasound" OR "ultrasound guid*" OR "ultrasonography" OR "sonography") AND ("Emergency Service, Hospital" OR "emergency department" OR "emergency service" OR "emergency nursing") AND ("nurs*"))
Cinahl	(MH Catheterization, Peripheral OR TI peripheral venous cannul* OR AB peripheral venous cannul* OR TI peripheral intravenous cannul* OR AB peripheral intravenous cannul* OR TI peripheral vascular cannul* OR AB peripheral vascular cannul* OR TI peripheral line OR AB peripheral line OR TI peripheral intravenous line OR AB peripheral intravenous line OR TI peripheral venous line OR AB peripheral venous line OR TI peripheral intravenous catheter* OR AB peripheral intravenous catheter* OR TI Peripheral Venous catheter* OR AB Peripheral Venous catheter* OR TI peripheral vascular catheter* OR AB peripheral vascular catheter* OR TI peripheral vascular access OR AB peripheral vascular access OR TI peripheral IV access OR AB peripheral IV access OR TI peripheral venous access OR AB peripheral venous access OR TI peripheral intravenous access OR AB peripheral intravenous access) AND (MH ultrasonography OR AB ultrasound OR TI ultrasound OR AB ultrasound guid* OR TI ultrasound guid* OR AB sonography OR TI sonography) AND (MH Emergency Service, Hospital OR AU emergency department OR AB emergency department OR AU emergency service OR AB emergency service OR MW emergency nursing) AND (TI nurs* OR AB nurs*)

2.3. Inclusion and exclusion criteria

Original studies from any date, published in English or Spanish that assessed the efficacy of the ultrasound-guided peripheral intravenous cannulation technique performed by emergency department nurses were included. No filters were applied to the databases results.

Publications that were not related to the topic or that did not show disaggregated data for emergency nurses were excluded.

2.4. Study selection process

The study selection process was carried out in various stages. The first phase involved an initial selection according to title and abstract, excluding those articles that were not available in Spanish or English and studies not related to the study topic. The second phase involved a more exhaustive analysis of the complete texts of the studies selected in the previous phase, with the selection of those that fulfilled the established inclusion criteria. Lastly, an inverse search was carried out from the bibliography of the selected studies. The selection process was done independently by two members of the team (LAM and JLGU), with a third member being consulted in case of disagreement (NSM).

2.5. Quality assessment

The OCEBM levels of evidence system was used to identify the level of evidence and degree of recommendation of each study. The entire process was carried out independently by two team members (LAM and JLGU), with a third member (NSM) being consulted in the event of discrepancies. The quality assessment was carried out with Critical Appraisal Skills Program (CASPe) checklists, using the 3 elimination questions depending on the type of the study.

2.6. Data extraction

The following variables were collected from each study: year of publication, country of study, design, sample size, characteristics of cannulised patients, ultrasound device used and main results.

2.7. Statistical analysis

The studies were subjected to a descriptive analysis. Two *meta*-analyses were performed, one of clinical tests to compare the success of peripheral cannulation with the use of the ultrasound-guided vs. the traditional technique and another to analyse the success percentage for the ultrasound-guided technique. Heterogeneity was analysed with I2 and publication bias with Egger's test. The RevMan Web and Statsdirect software programs were used.

3. Results

3.1. Search results

In the search, 49 articles were recovered from Scopus, of which 30 were selected according to title and abstract. From Pubmed, 42 articles were recovered, 40 of which were excluded due to being duplicated in Scopus. The 2 remaining articles were rejected following a first reading of the title and abstract. From CINAHL, 32 articles were recovered, of which 24 were rejected for being duplicated in Scopus and/or PubMed. Following the analysis of the title and abstract of the 8 remaining articles, 2 studies were selected for a reading of their complete text.

A total of 32 articles were chosen for a complete text review and 26 of them were selected for an in-depth reading. 4 of these studies did not show disaggregated data for emergency nurses and in 4 documents the data reported were insufficient for inclusion. An inverse search was carried out in which 2 documents were recovered from the bibliography of the primary studies selected. Thus, a total of 20 articles were included in the review [26–45] (Fig. 1).

3.2. Characteristics of studies included

The studies included in the review were published between 2004 and 2022, 80 % (n = 18) in the last 10 years. Regarding the geographical distribution of the articles, 75 % (n = 17) were written in the United States (USA), two in Spain, two in Turkey and one in Italy (Table 2).

As regards the design of the studies, 70 % (n = 16) of the articles analysed were descriptive, nine cross-sectional and five longitudinal. Of the six analytical studies, three were random clinical trials, one quasi-experimental, one case study and one retrospective cohort study (Table 2).

Regarding sample size, the range of emergency department nurses included in the studies was highly variable, oscillating between 4 and 83 nursing professionals. Three articles did not show data on the number of nurses who participated (Table 2).

In relation to patients on whom ultrasound-guided peripheral intravenous cannulation was performed, the majority of the studies analysed adult populations [28,37,31–35,42–45], 82 % of which examined adults with difficult intravenous access. However, in two articles, the cannulation was performed on paediatric patients [40,41]. The study included both adult and paediatric patients aged over [12] populations [36]. Two studies did not provide information on the age range of the cannulised patients and three publications did not show any data relating to them (Table 2).

In terms of device used, 70 % of the studies provided information on the ultrasound scanner employed. In over two-thirds of these studies different ultrasound devices from the SonoSite company were used [26–29,31,32,34–36,41,43] All of the authors who reported the type of transducer employed in their study indicated the use of a linear probe. In regards to frequency used, considerable variability between the articles was found (frequency ranges situated between 5 and 14 MHz) (Table 2).

3.3. Success rate using ultrasound for peripheral intravenous cannulation

65 % of the studies measured the success rate of ultrasound-guided peripheral intravenous cannulation per patient [26–28,30,32,33,35–39,41,44]. The percentage of success varied from between each one, with 63 % [28] being the minimum and 96.45 % [44] the maximum obtained. However, in most of the texts [26,27,30,33,37,38,44] the success of the technique stood above 85 %. İsmailoğlu et al [31] and Bahl et al. [35] observed greater success rates using USG-PIVC in patients with DIVA than with the traditional technique; moreover, the difference between both procedures was statistically significant.

40 % of the articles examined the success rate in the first attempt of ultrasound-guided peripheral intravenous cannulation [28,30,32,37,40,43–45]. Successes at the first attempt all stood above 72 % except for one article in which considerably lower rates were obtained (20 %) [32]. 50 % of these studies reflected success rates over 83 % [28,30,37,40], with a maximum of 87 % [40]. Salleras-Duran [37] and Yalçınlı et al. [43] showed success rates at the first attempt that were significantly higher with the ultrasound-guided technique compared to the standard one.

Two studies analysed the success of USG-PIVC according to the cut or axis used in patients with difficult intravenous access. Blaivas et al. [27] reflected a success rate of 89 % with the cross-sectional cut and 85 % with the longitudinal cut. Privitera et al. [44] obtained greater rates of 96.45 % with the short axis and 92.25 % with the long axis. In both studies the success rates using the cross-sectional cut were higher; however, the difference was not statistically different in either of them.

Two studies compared the success of the USG-PIVC technique amongst professionals. Nurses obtained significantly higher success rates than technical staff [36]. Carter et al. [33] observed similar rates between nurses and doctors of 86 % and 85 %, respectively.

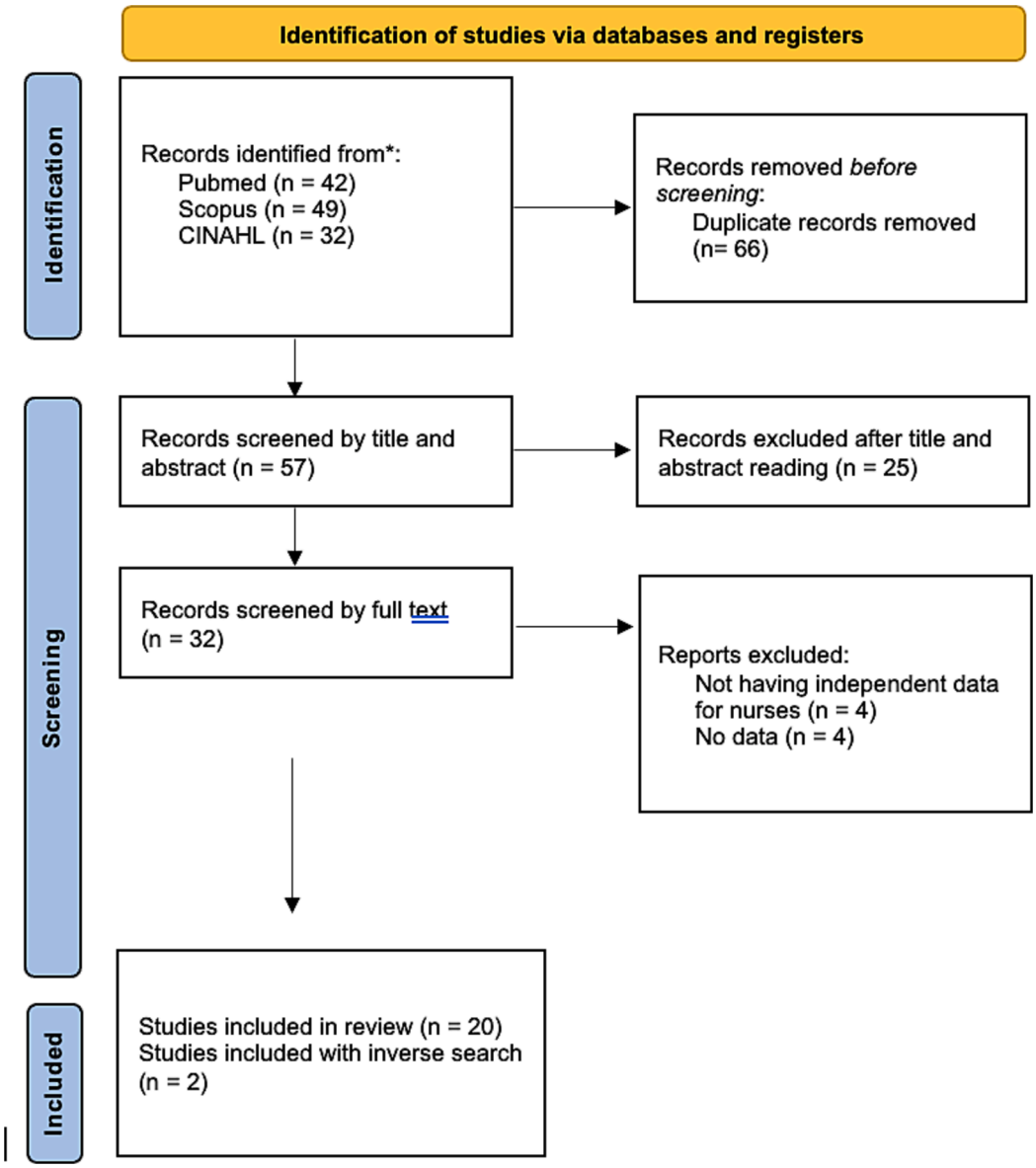

Fig. 1. Diagram of document selection.

Nevertheless, Oliveira et al. [36] showed rates that were higher in doctors (79.4 %) compared to nurses (63.2 %).

3.4. Number of attempts and time using ultrasound for peripheral intravenous cannulation

The mean number of attempts varied according to the different studies from 1.51 to 2.07 [31,32,35]. In these analyses, the number of attempts between the ultrasound-guided and traditional techniques were compared, with the mean number of attempts necessary for USG-PIVC being lower than Standard technique-PIVC in all of them; nevertheless, a statistically significant difference was not obtained in any [31,32,35]. Blick et al. [40] and Yalçınlı et al. [43] used the median as a measurement, obtaining 1.1 and 1 attempts, respectively.

The mean time for the successful placement of a USG-PIVC in patients with difficult intravenous access was measured by four studies, which obtained highly diverse results. Yalçınlı et al. [43] and Rodríguez-Herrera [45] et al. showed more similar figures, an average cannulation time of 107 and 126.17 s, respectively. However, the duration up to achieving success in the procedure was greater in the studies of Weiner et al. [31] and Bahl et al. [35], 27.6 and 15.8 min, respectively. Furthermore, mean catheter duration time was 2.6 days for both USG-PIVC and ST-PIVC [34].

3.5. Clinical outcomes and patient satisfaction using ultrasound for peripheral intravenous cannulation

Pain perceived by the patient during the ultrasound-guided technique was studied in five articles. However, the authors used different scales for their measurements. In their results Salleras-Duran et al. [37] reflected a moderate perception of pain (score: 5.16) on the part of their patients using the Verbal Rating Scale (VRS). Privitera et al. [44] used the Numeric Rating Scale (NRS), with the patients in this study communicating a mean level of pain both in the cross-sectional and longitudinal axis procedure (scores: 2.59 and 2.71, respectively). Three scales used the visual analogue scale (VAS) and compared the level of pain during ultrasound-guided peripheral intravenous cannulation with the traditional technique [31,32,45]. In the three publications the perceived level of pain by the patients was moderate during both procedures. Nevertheless, they all reflected a lower level of pain using the

Table 2
Summary of selected documents.

Authors, year and country	Design	Sample	Cannulised patients	Ultrasound device, transducer	Main results	LE/ DR
Brannam et al., 2004 [26] USA	Descriptive cross-sectional study	23 emergency department nurses	321 patients with DIVA (age not featured)	SonoSite ILook 25, 7.5 MHz linear transducer	• USG-PIVC success: 87 % • Incidence of associated complications: 1.2 % (arterial puncture)	4/C
Blaivas et al., 2006 [27] USA	Descriptive cross-sectional study	23 emergency department nurses	321 patients (age not featured)	SonoSite ILook 25, 7.5 MHz linear transducer	• USG-PIVC success (cross-sectional vs. longitudinal cut): 89 % vs. 85 % (p = 0.21)	4/C
Chinnock et al., 2007 [28] USA	Descriptive cross-sectional study	18 emergency department nurses	100 adult patients with DIVA	SonoSite ILook 25, 7.5 MHz linear transducer	• USG-PIVC success: 63 % (IC95% 53–72 %) • Success at 1st cannulation attempt: 83 % • Incidence of associated complications: 16 % (5 % arterial puncture, 3 % MS numbness, 8 % severe pain)	4/C
Miles et al., 2012 [29] USA	Descriptive cross-sectional study	45 emergency department nurses	Not featured	SonoSite MicroMaxx portable, transducer not featured.	• 74 % decrease in cannulation of central veins (PICC and CVC)	4/C
Moore, 2013 [30] USA	Descriptive cross-sectional study	Not featured	Not featured	Site Rite (Bard Access Systems), mechanical transducer.	• USG-PIVC success: 94.7 • Success at 1st cannulation attempt: 86.5 %	4/C
Weiner et al., 2013 [31] USA	Descriptive cross-sectional study	Not featured	50 adult patients with DIVA 29 USG-PIVC 21 ST-PIVC	Zonare z.one ultra, linear transducer SonoSite M−Turbo, linear transducer	• Mean no. attempts (USG-PIVC vs. ST-PIVC): 2.0 (IC95% 1.5–2.4) vs. 2.1 (IC95% 1.6–2.6), p = 0.57 • Procedure time (USG-PIVC vs. ST-PIVC): 27.6 min (IC 95 % 16.0–39,1) vs. 26.4 min (IC 95 % 16.8–36.0), p = 0.88 • Pain level (USG-PIVC vs. ST-PIVC): 4.9 (IC 95 %: 3.6–6.1) vs. 5.5 (IC 95 %: 4.1–6.9), p = 0.50. • High patient satisfaction (USG-PIVC vs. ST-PIVC): 86.2 % vs. 63.2 %, p = 0.06 • Medical intervention (USG-PIVC vs. ST-PIVC): 24.1 % vs. 52.4 %, p = 0.04	4/C
İsmailoğlu et al., 2015 [32] Turkey	Descriptive cross-sectional study	4 emergency department nurses	60 adult patients with DIVA 30 USG-PIVC 30 ST-PIVC	SonoSite Micromaxx (portable), 13.5 Mhz transducer	• Success in USG-PIVC vs. ST-PIVC: 70 % vs. 30 % (X^2 = 9.60, p = 0.002) • Success 1st attempt (USG-PIVC vs. ST-PIVC): 20 % vs. 10 % (X^2 = 1.176, p = 0.278) • Mean no. attempts (USG-PIVC vs. ST-PIVC): 2.07 ± 0.65 vs. 2.10 ± 0.61 (t = 0.189, p = 0.850) • Pain intensity (USG-PIVC vs. ST-PIVC): 4.77 ± 1.74 vs. 6.00 ± 1.98 (t = 2.564, p = 0.013) • Incidence of associated complications: (USG-PIVC vs. ST-PIVC): 30 % vs. 46.7 % (X^2 = 1.763, p = 0.182)	4/C
Carter et al., 2015 [33] USA	Quasi-experimental study	11 emergency nurses and 5 doctors	90 adult patients with DIVA	Not featured	• Success in USG-PIVC by nurses vs. doctors: 86 % vs. 85 % (p = 0.305) • Incidence of associated complications by nurses vs. doctors: 0 % vs. 5 %.	2b/ B
Adhikari et al., 2010 [34] USA	Retrospective longitudinal descriptive study	7 emergency department nurses	764 adult patients	SonoSite ILook 25, 10–5 MHz linear transducer	• Mean catheter duration time (USG-PIVC vs. ST-PIVC): 2.6 vs. 2.4 days (p = 0.03) • Infection rates (USG-PIVC vs. ST-PIVC): 5.2 ‰ vs. 7.8 ‰ (p = 0.68)	4/C
Bahl et al., 2016 [35] USA	Random controlled trial	20 emergency nurses.	122 adult patients with DIVA: 63 USG-PIVC 59 ST-PIVC	SonoSite M−turbo, high frequency linear transducer.	• Success in USG-PIVC vs. ST-PIVC: 76 % vs. 56 % (p = 0.02) • OR success in USG-PIVC compared to ST-PIVC: 2.52 (IC95%, 1.09–5.92) • $\bar{X}$ time of USG-PIVC vs. ST-PIVC: 15.8 min vs. 20.7 min (p = 0.75) • No. attempts per patient (USG-PIVC vs. ST-PIVC): 1.52 vs. 1.71 (p = 0.61)	1b/ A
Oliveira et al., 2016 [36] USA	Descriptive cross-sectional study	8 emergency nurses, 10 doctors and 8 technical staff.	65 patients > 12 years of age (13–85)	SonoSite M−Turbo Linear transducer, 13–6 MHz	• Success in USG-PIVC: doctors, 79.4 %; nurses, 63.2 %; technical staff, 50 %.	4/C
Salleras-Duran et al., 2016 [37] Spain	Descriptive cross-sectional study	14 nurses	103 adult patients	Not featured	• USG-PIVC success: 95.1 % • Success at 1st cannulation attempt: 84.2 % • Level of pain (VRS scale, 0–10): 5.16 (DE, 2.63) • Level of satisfaction (0–10): 7.62 (DE, 2.41)	4/C
Feinsmith et al., 2018 [38] USA	Prospective longitudinal descriptive study	34 emergency department nurses	Not featured	Not featured	• Success in USG-PIVC (1–10 attempts vs. 21–30 attempts): 81 % vs. 96 % (P = 0.0001)	4/C

(*continued on next page*)

Table 2 (*continued*)

Authors, year and country	Design	Sample	Cannulised patients	Ultrasound device, transducer	Main results	LE/DR
Huang C et al., 2018 [39] USA	Prospective longitudinal descriptive study	12 emergency department nurses	172 patients with DIVA (age not featured)	Not featured	• USG-PIVC success: 76 % • 26 % reduction in consultations to iv access team (p = 0.048) • 32 % reduction in CVCs (p = 0.015) • Incidence of associated complications: 1.5 % (arterial puncture)	4/C
Blick et al., 2020 [40] USA	Retrospective longitudinal descriptive study	83 emergency department nurses	4053 paediatric patients	Not featured	• Success at 1st USG-PIVC attempt: 87 % (3513/4053). • Mean no. attempts: 1. (range: 1, 1.5) • Associated complication rate: 25 %	4/C
Anderson et al., 2021 [41] USA	Prospective longitudinal descriptive study	15 emergency department nurses	334 paediatric patients	SonoSite X-Porte and SonoSite SII, 13–6 Mhz linear transducer	• USG-PIVC success: 75 %	4/C
Davis et al., 2021 [42] USA	Retrospective cohort study	Not featured	2816 adult patients with DIVA	Not featured	• Time until insertion of catheter by USG-PIVC > 2 h (nurses vs. doctors): 42.1 % vs. 61.8 % • Time until laboratory results > 2 h (nurses vs. doctors): 38.4 % vs. 54.1 % • Time until IV analgesia > 2 h (nurses vs. doctors): 71.6 % vs. 78.6 % • Time in emergency > 6 h (nurses vs. doctors): 58.7 % vs. 63.8 % • OR (USG-PIVC inserted by nurses): time until IV insertion > 2 h, 0.42 (IC 95 %, 0.38–0,47); time until laboratory results > 2 h, 0.49 (IC 95 %, 0.44–0,55); time until IV analgesia > 2 h, 0.68 (IC 95 %, 0.57–0.81); stay in emergency > 6 h, 0.79 (IC 95 %, 0.71–0.88).	2b/B
Yalçınlı et al., 2022 [43] Turkey	Random controlled trial	6 emergency department nurses	270 adult patients with DIVA: 90 from each group (USG-PIVC, ST-PIVC, infrared)	SonoSite Edge, transducer not featured.	• Success at 1st attempt by groups (p = 0.010): USG-PIVC (78.9 %); ST-PIVC 62.2 %); infrared (58.9 %). • Procedure time by groups (p = 0.001): USG-PIVC, 107 s (69–228); ST-PIVC, 72 s (47–134); Infrared, 82 s (61–163) • Mean no. attempts: USG-PIVC, 1 (1–1); ST-PIVC, 1 (1–2); infrared, 1 (1–2). A difference was found between the USG-PIVC and infrared groups (P = 0.014).	1b/A
Privitera et al., 2022 [44] Italy	Random controlled trial	6 emergency department nurses	283 adult patients with DIVA 141 T-axis 142 L-axis	MyLab Alpha (Esaote), 5–14 MHz linear transducer	• USG-PIVC success (cross-sectional vs. longitudinal cut): 96.45 % (IC 95 % 91,92–98,84) vs. 92.25 % (IC 95 % 86.56–96.07), p = 0.126. • Success 1st attempt (cross-sectional vs. longitudinal cut): 76 % vs. 69 % (p = 0.207) • Perceived pain (NRS) in cross-sectional and longitudinal cut: 2.59 (DE 2.02) and 2.71 (DE 2.13) • Incidence of associated complications during admission: 12.02 % (4.24 % leakage, 4.95 % infiltration and 2.83 % occlusion)	1b/A
Rodriguez-Herrera et al., 2022 [45] Spain	Cases and controls	Not featured	72 adult patients with DIVA 38 ST-PIVC 34 USG-PIVC	LOGIQ P5 750VA (GE Healthcare), 11 Mhz linear transducer	• Success 1st attempt (USG-PIVC vs. ST-PIVC): 76 % vs. 16 % • Procedure time of USG-PIVC vs. ST-PIVC ($\bar{X}$): 126.17 s ± 101.09 vs. 618.34 s ± 387.16 (p < 0.001) • Pain (EVA scale) USG-PIVC vs. ST-PIVC ($\bar{X}$): 4.58 ± 2,03 vs. 6.55 ± 1.70 (p = 0.023) • Associate complications (ecchymosis, haematoma and extravasation) in USG-PIVC vs. ST-PIVC: 26.5 % vs. 79 % (p < 0.001)	3b/B

LE/DR: Level of Evidence/Degree of Recommendation; USG-PIVC: Ultrasound-Guided Peripheral Intravenous cannulation; ST-PIVC: Standard Technique Peripheral Intravenous cannulation; DIVA: Difficult Intravenous Access; PICC: Peripherally Inserted Central Catheter; CVC: Central Vein Catheter; OR: Odds Ratio; C-axis: Cross-sectional axis; L-axis: longitudinal axis.

ultrasound-guided technique compared to the standard method (USG-PIVC vs. ST-PIVC scores: 4.9 vs. 5.5; 4.7 vs. 6; 4.58 vs. 6.55); in addition, İsmailoğlu et al. [32] and Rodríguez-Herrera et al. [45] showed that the difference between the procedures was statistically significant.

40 % of the articles examined complications related to the USG-PIVC technique and the incidence thereof. The complications associated with the moment of puncture were studied by the majority of the authors, who obtained highly variable incidence rates, from 0 % to 30 % [26,28,32,33,39,40,45]. Privitera et al. [44] observed a complications incidence of 12.02 % during patient emergency department admission (leakage, infiltration and occlusion). Two studies [32,45] compared the incidence of puncture associated complications between the ultrasound-guided and traditional cannulation techniques, with the incidence being lower for both studies in USG-PIVC; in addition, Rodríguez-Herrera et al. [45] reflected that the difference was significant. Furthermore, lower infection rates (5.2 per 1000 vs. 7.8 per 1000) were obtained with the ultrasound cannulation procedure compared to the standard technique [34].

86.2 % of patients cannulised with the ultrasound-guided technique showed high satisfaction compared to 63.2 % with the standard technique [31]. Satisfaction with the USG-PIVC technique was also measured by Salleras-Duran et al. [37], with patients communicating a mean satisfaction level of 7.62 (0-10points).

Davis et al. [42] reported that USG-PIVCs cannulised by nurses were associated with more efficient care (less delay in canulation, laboratory results and analgesic administration, and less time spent by patients in the emergency department) in comparison with USG-PIVCs cannulised by physicians.

Three articles studied the need for rescue interventions following the training of emergency nurses in the USG procedure. Miles et al. [29] reflected a 74 % reduction in central vein cannulation (CVCs or PICCs) in the emergency department following training. Huang et al. [39] reported a 26 % reduction in consultations to the access team and a 32 % reduction in CVCs following training. Weiner et al. [31] observed less need for medical intervention following the PIC cannulation attempt in a patient with DIVA with the ultrasound-guided technique (24,1%) compared to the traditional method (52,4%).

3.6. *Meta-analysis*

In the fixed effects *meta*-analysis of clinical trials for analysing the efficacy of the ultrasound-guided vs. the traditional technique n = 2 studies were included that contained the information. With an n = 149 control group and an n = 153 experimental group a lower probability of success was obtained as regards peripheral intravenous cannulation when the standard technique was used, OR = 0.42 (95 %CI 0.25–0.70p < 0,05) (Fig. 2). The I^2 heterogeneity value was 0 %.

Regarding the *meta*-analysis of the success rate with the ultrasound-guided technique in emergency departments, with an n = 6 study sample there was an 80 % success observed (95 %CI 69 %-89 %) with n = 940 attempts. A *meta*-analysis of random effects was carried out and the I2 stood at 92.3 % (Fig. 3).

4. Discussion

The aim of this review was to examine the efficacy of the ultrasound-guided peripheral intravenous cannulation technique carried out by emergency department nurses. To our knowledge this is the first review centred on the USG-PIVC technique that only includes studies using samples of emergency department nurses.

The results indicate that it increased both the likelihood of general success in the procedure [32,35] and of a successful first attempt [37,43], compared to the traditional technique of visualisation and palpitation, findings that coincide with the *meta*-analysis by Tran et al. [46], which analysed the procedure carried out by nurses in different units (ICU, surgery and emergency departments). Along this same line, previous *meta*-analyses compared the efficacy of USG-PIVC with ST-PIVC by different healthcare professionals (nurses, doctors and technical staff) and observed an association between USG-PIVC and higher success rates in general [47] and at the first attempt [48].

Furthermore, Carr et al [49] showed that the first attempt success rate for PIVC cannulation by emergency department nurses stood at 63 %. In this review higher success rates using ultrasound have been observed, 72 % in all the studies that analysed this variable [28,30,37,40,43–45] except one of them [32]. Moreover, this percentage reached values higher than 83 % in half of the publications [28,30,37,40].

In relation to pain perceived by the patient during cannulation of a peripheral intravenous line, it has been demonstrated that USG-PIVC is associated with a significantly lower pain level than the standard technique [32,45]. In contrast, no evidence has been found to support the use of ultrasound by emergency nurses to reduce procedure duration time, given that the results obtained by the studies were contradictory [31,35,43,45]. Nor were significant differences detected as regards the number of attempts between the ultrasound and standard procedure, despite various studies reporting that the number of skin punctures was lower in the former [31,32,35]. These results coincide with the *meta*-analysis of Slotz et al [47].

The complications associated with ultrasound-guided peripheral intravenous cannulation were diverse, with highly variable rates amongst the studies (0——30 %) [26,28,32,33,39,40,44,45]. The difference between the complication rates of some studies and others may be due to the variability between the complications measured by each article, as well as their cross-sectional or longitudinal nature. The two studies [32,45] that compared the incidence of the complications associated with puncture between the ultrasound-guided technique and the traditional method showed a lower incidence in the case of USG-PIVC; nevertheless, only in one of them was the difference significantly lower [45].

The two publications that studied patient satisfaction with USG-PIVC carried out by nurses observed high satisfaction [31,37]. Nevertheless, despite Weiner et al. demonstrating that patient satisfaction was greater in the USG-PIVC group than the ST-PIVC group, the difference did not reach statistical significance.

Although the need for a rescue intervention in the face of failure to obtain a PIC was only studied by three articles, the results suggest that the training of emergency nurses in the ultrasound-guided cannulation technique significantly reduces CVC cannulation in emergency departments, along with intervention on the part of doctors or specialist vascular teams [29,31,39].

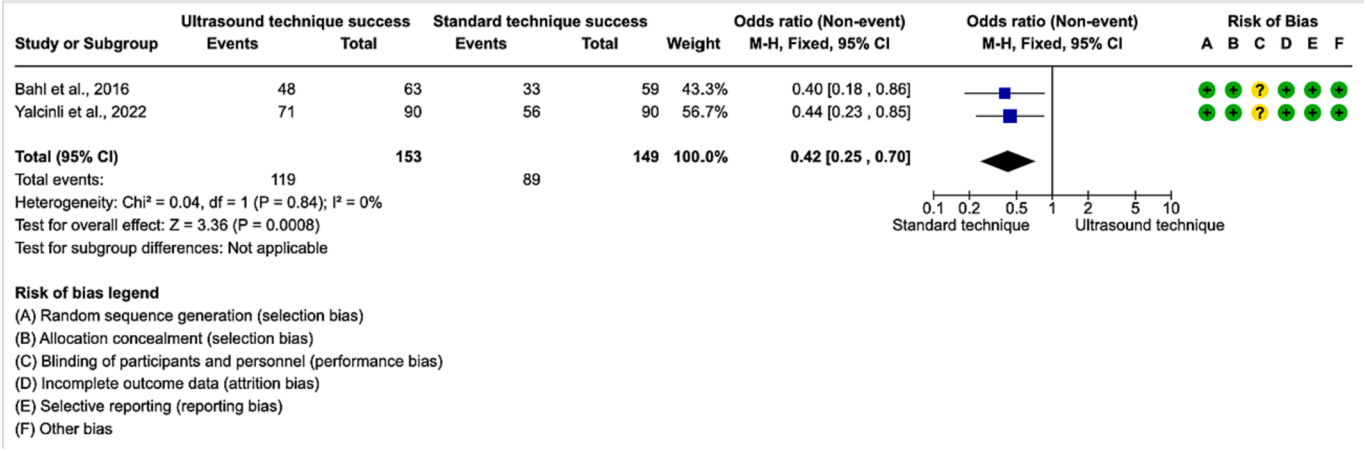

Fig. 2. Forest plot of success in peripheral intravenous cannulation with standard vs. ultrasound-guided technique.

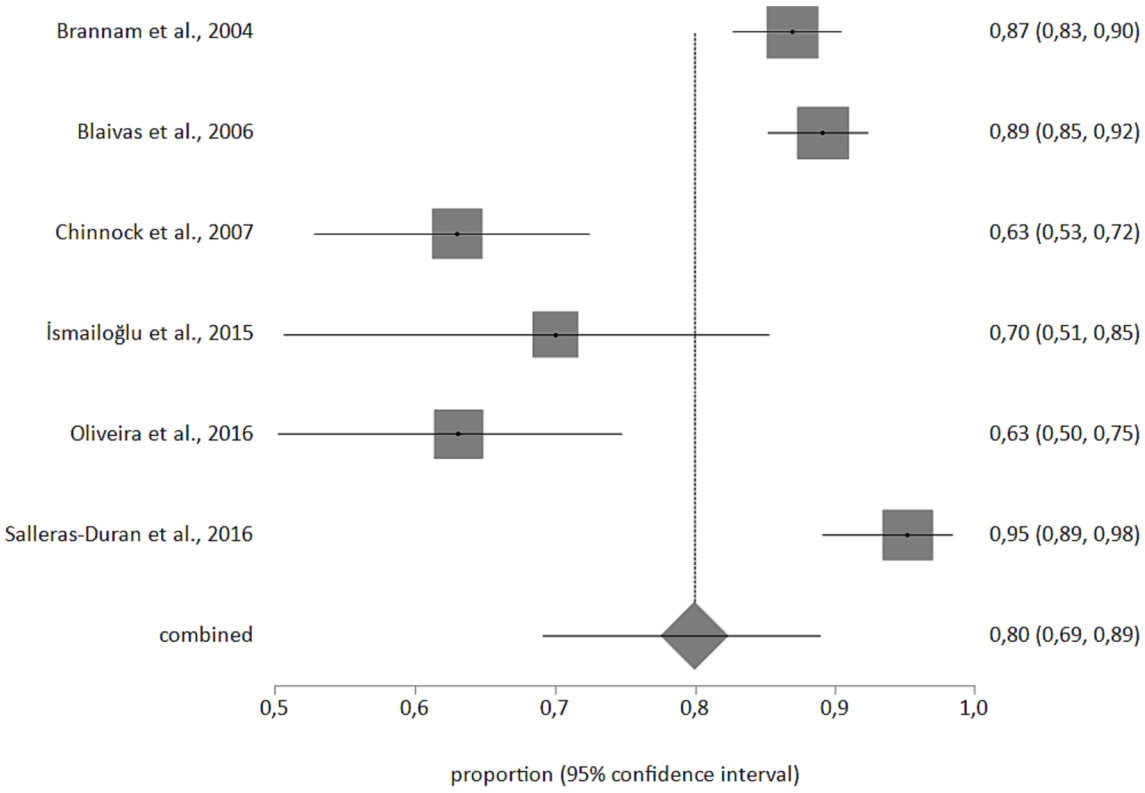

Fig. 3. Forest plot of success rate for peripheral intravenous cannulation with ultrasound-guided technique.

5. Limitations

This review contains some limitations. Firstly, most of the studies it includes are observational with a low evidence level, in addition to being carried out in different countries with different healthcare systems and nurse training profiles, suggesting that the findings should be interpreted with caution. Another limitation was the variability of cannulised patients in relation to age and the presence of difficult intravenous access. Most of the articles studied adult patients with DIVA; however, the definition of this characteristic varied considerably between the studies. This may limit the generalisation of the results due to the considerable heterogeneity of the cannulised patients. Lastly, the number of studies included in the *meta*-analyses was low.

6. Future research and clinical implications

It is evident that there is a need to design future studies of an analytical nature on the efficacy of ultrasound-guided peripheral intravenous cannulation carried out by emergency department nurses, given that most of the studies published are descriptive. It would, furthermore, be interesting to develop studies that compare and analyse the different USG-PIVC nurse training programmes, and cost-effectiveness.

Regarding the implications in clinical practice, this review shows that the ultrasound-guided peripheral intravenous cannulation technique applied by emergency department nurses is a safe and effective procedure. The findings of this review underline the importance of healthcare institutions in the training of emergency department nurses in the use of the ultrasound scanner for cannulising PICs for the benefit of patients who make use of this service and, more specifically, patients with difficult intravenous access. It is also important to indicate that specific practice and training in peripheral intravenous cannulation and the use of the ultrasound machine for this purpose should enhance the results of both techniques, improving the skills of nurses.

7. Conclusions

The USG-PIVC technique employed by emergency service nurses increased both the probability of general success and of a first successful attempt compared to the standard technique. However, the ultrasound-guided method did not have a significant effect on the time necessary for obtaining a successful cannulation or the number of attempts required. With USG-PIVC, patients showed a high level of satisfaction with the technique and lower rates of associated complications.

In general terms, the studies included in our review supported the efficacy of ultrasound-guided peripheral intravenous cannulation carried out by emergency department nurses.

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CRediT authorship contribution statement

Lorena Álvarez-Morales: Writing – original draft, Methodology, Investigation, Conceptualization. **José L. Gómez-Urquiza:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Nora Suleiman-Martos:** Writing – original draft, Visualization, Validation, Supervision, Investigation, Formal analysis. **María José Membrive-Jiménez:** Data curation, Formal analysis, Investigation, Methodology, Resources, Software. **Ana González-Díaz:** Writing – review & editing, Visualization, Software, Resources, Formal analysis. **Raquel García Pérez:** Project administration, Methodology, Investigation, Conceptualization. **Antonio Liñán-Gonzalez:** Writing – review & editing, Visualization, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial

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