Handheld Ultrasound Devices for Peripheral Intravenous Cannulation

A Scoping Review

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ABSTRACT

Ultrasound-guided insertion of peripheral intravenous catheters (PIVCs) is recommended for patients with difficult intravenous access, but access to ultrasound equipment is often limited to specialty departments. Compact, affordable handheld ultrasound devices are available, but the extent of their clinical adoption and impact on patient outcomes is unknown. This scoping review aimed to explore evidence regarding handheld and pocket ultrasound devices for PIVC insertion. Databases were searched for studies published in English between January 2000 and January 2023

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evaluating handheld or pocket ultrasound devices weighing ≤3 kg for PIVC insertion. Data were extracted using standardized forms and summarized using descriptive statistics. Seventeen studies reporting the use of handheld or pocket ultrasound devices were identified. Most studies were conducted in adult inpatient facilities; 3 included pediatrics, and 2 reported out-of-hospital use. Participants with difficult intravenous access featured in 9 studies. Ultrasound training programs were described in 12 studies, with competency defined by number of successful PIVC insertions. Five studies reported clinician and/or patient perspectives. Ultrasound for PIVC insertion is not widely accessible in nonspecialist areas, but more compact and affordable handheld models could provide a solution, especially for patients with difficult access. More research evidence using handheld ultrasound is needed.
Key words: catheterization, handheld, medical device, peripheral intravenous catheter, ultrasound-guided insertion

INTRODUCTION

Successful peripheral intravenous catheter (PIVC) insertion requires careful selection of vessels of suitable size, width, depth, length, and site.[1] These criteria cannot always be met with standard insertion techniques (landmark or palpation), as clinicians are unable to "see" or find suitable vessels. Up to 70% to 90% of hospital patients require a PIVC,[2-4] but insertion is often challenging and difficult using standard methods, with first insertion failure rates of up to 75% and many patients experiencing multiple painful attempts.[5] Ultrasound guidance (USG) is increasingly recommended for achieving PIVC insertion success, particularly in patients with difficult intravenous access (DIVA)[6-8] and to preserve vessel health.[9] Despite commercial availability of ultrasound machines, their uptake in clinical practice remains limited primarily to specialist clinicians and settings. The most frequently cited barriers to uptake and adoption include limited access to equipment, purchase and upkeep costs, low technical knowledge and/or skills, lack of available ultrasound education, and lack of evidence and guidelines for ultrasound PIVC insertion.[10]

The weight of ultrasound devices usually determines their mode of transportation to the patient, and while there is no concrete classification system, devices can be cart-mounted, hand-carried, handheld, or pocket-sized. Compact ultrasound units and viewing platforms on tablets, phones, inbuilt probe screens, and all-in-one wireless probes[11] are increasingly available and affordable and, as such, are expected to become the "stethoscope of the 21st century."[12] Hand-carried ultrasound systems feature probes, screens, and control panels with a combined weight usually <3 kg, but these systems may also be cart- or pole-mounted.[13] Handheld and pocket ultrasound devices refer to compact, lightweight (usually <1 kg) systems including probes, screens, and control panels, which fit in clothing pockets of clinicians, and many of these devices can be connected to a smart phone.[13] Portability and affordability of these smaller devices provides a potential solution to clinical and resource challenges associated with standard cart-mounted ultrasound technology.

The aim of this scoping review was to explore the literature and evidence to date, focusing on the clinical uptake of compact handheld or pocket-sized ultrasound devices for PIVC insertion since the year 2000. The findings from the review may serve to guide program and policy development, identify research gaps to improve future research protocols, and ensure adequate and successful implementation of this rapidly expanding technology.

The Scoping Review Questions Were the Following:

1. What are the characteristics of studies (population, demographics, and clinical settings) focusing on compact handheld ultrasound devices for PIVC insertion conducted since the year 2000?
2. What compact handheld ultrasound equipment and insertion procedures are featured in the selected literature?
3. What outcome measures on compact handheld USG PIVC insertion have been reported in the literature (eg, number of insertion attempts, time to insertion, PIVC outcomes, complications, or failure)?
4. What interventions and education strategies for teaching and learning have been adopted for the promotion, use, and support of compact handheld ultrasound devices for PIVC insertion, and what measures define competence and expertise?
5. What is the experience and/or perspective of clinical users and patients toward compact handheld ultrasound devices for PIVC insertion?

METHODS

This scoping review was conducted according to the Arksey and O'Malley scoping review framework,[14] the components and elements of Anderson et al,[15] and the methodologic recommendations for scoping studies by Levac et al.[16] Further details are in the published scoping review protocol.[17] The results are reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR).[18]

Eligibility Criteria

Included studies used point-of-care ultrasound equipment weighing <3 kg for PIVC insertion, including preinsertion assessment. Ultrasound terminology, including *point-of-care* or *handheld* or *hand-carried,* indicated the clinician performing the procedure arrived at the patient's bedside or other location carrying the compact ultrasound system. All named ultrasound models were checked for online manufacturer-reported weight specifications. If an ultrasound machine weighing <3 kg was identified as cart-mounted, it was included in the review.

Qualitative, quantitative, experimental, or quasi-experimental studies comparing hand-carried, handheld, or pocket-sized point-of-care devices with cart-mounted ultrasound equipment or standard methods for PIVC insertion across all age groups were considered. Qualitative studies describing clinician and/or patient experiences and satisfaction with handheld pocket or hand-carried devices, either as user opinion or verdict or in comparison with traditional ultrasound equipment, near infrared and transillumination devices, or standard PIVC insertion techniques were also included.

Excluded studies were those using ultrasound equipment weighing >3 kg (or a combination of ultrasound devices with some weighing >3 kg, unless the results were reported individually for each device type). Other exclusions were insertion of central venous devices or arterial lines, studies using only phantom arms or vessels, animal studies, conference abstracts, and editorials, letters, commentary, and opinion pieces with minimal or no study data provided.

Information Sources

Search terms included variations of pocket or handheld or hand-carried ultrasound and peripheral intravenous catheter/cannula. This yielded limited results and was amended to (peripheral vascular) OR (peripheral venous) OR (peripheral intravenous) OR (peripheral intravascular) OR (peripheral cannula*) OR (peripheral catheter*) OR (peripheral access*) AND (Ultrasound* OR ultrason*) AND Insert*. Searches were conducted across PubMed, National Library of Medicine (Medline) via OVID, Cumulative Index to Nursing and Allied Health (CINAHL), Excerpta Medica Database (Embase), Web of Science, Scopus, Cochrane CENTRAL, Google Scholar, Clinicaltrials.gov, Australian New Zealand Clinical Trials Registry (ANZCTR), and International Clinical Trials Registry Platform (ICTRP) databases. Searches of unpublished studies were conducted in ProQuest Dissertations and Theses, Open Access Theses and Dissertations, and National Grey Literature Collection (MedNar). A Google search was also executed and results limited to the first 50 results for relevance.[19] Limiters for English and years between January 2000 and January 2023 were used. Reference lists of selected articles were searched for additional studies. Authors were contacted for clarification on weight of US equipment, but response rates were low, and weights were usually unknown by the respondents. (See Supplemental Digital Content 1 for search strategy, http://links.lww.com/JIN/A113).

Selection of Sources of Evidence

References were exported, screened, and managed using bibliographic software package EndNote 20 (Clarivate, Jersey, United Kingdom). Results from searches were imported, sorted into groups for each database, and duplicates were removed. Titles and abstracts were assessed for suitability, followed by full-text appraisal by 2 reviewers (GRB, PP) to ensure robust selection. A third reviewer for disagreements was not required.

Data Charting Process and Data Items

Data were extracted to a standardized data extraction form in Microsoft Excel (Microsoft, Redmond, WA) under the broad headings: author, year, setting, participants, methodology, type of ultrasound equipment, clinician training, insertion methods, DIVA populations, key themes, reported outcomes, funding, and limitations. Information was collected on ultrasound equipment manufacturer, brand, weight, viewing platform, transducers (probe) type, specifications and orientation used, ultrasound technique (static or dynamic), operator factors, and patient population (DIVA/non-DIVA). Static technique involves using ultrasound to locate and assess vessels but does not progress to real-time visualization of needle insertion, while dynamic technique involves ultrasound to locate and assess vessels and progresses to direct visualization of the needle as it enters the target vein in real time.[20]

Synthesis of Results

Data in Excel were summarized using descriptive statistics (frequency and percentages). Critical appraisal of included articles was not undertaken, as per the aims of the scoping review.

RESULTS

Search Results

A total of 23 078 studies were retrieved. Following removal of duplicates (n = 9068), 14 010 studies were screened for relevant title and/or abstract, and 148 full-text articles were read in full and assessed for eligibility. Following exclusion of studies reporting use of ultrasound devices weighing >3 kg, 17 studies including data from 5118 USG PIVCs were included in this scoping review (Figure 1).

Study Characteristics

Eight studies were conducted in the United States,[21-28] 3 studies in Japan,[29-31] 2 in Australia,[10,32] and 1 study each in the Czech Republic,[33] Denmark,[34] Italy,[35] and the Netherlands.[36] Study designs included 9 prospective observational cohort studies,[10,24-26,28,29,31,32,36] 2 randomized trials,[23,33] 3 prospective pre–post studies,[27,30,34] and 3 retrospective chart audits.[21,22,35] Most were conducted in single inpatient facilities (82%); 1 was a multicenter study,[36] and 2 studies reported ultrasound outcomes in prehospital settings.[10,33] Settings included emergency department,[21-25,28,35] ward settings,[29-31] telemetry,[26] operating suite and radiology,[36] and mixed settings.[27,32,34] Adults were

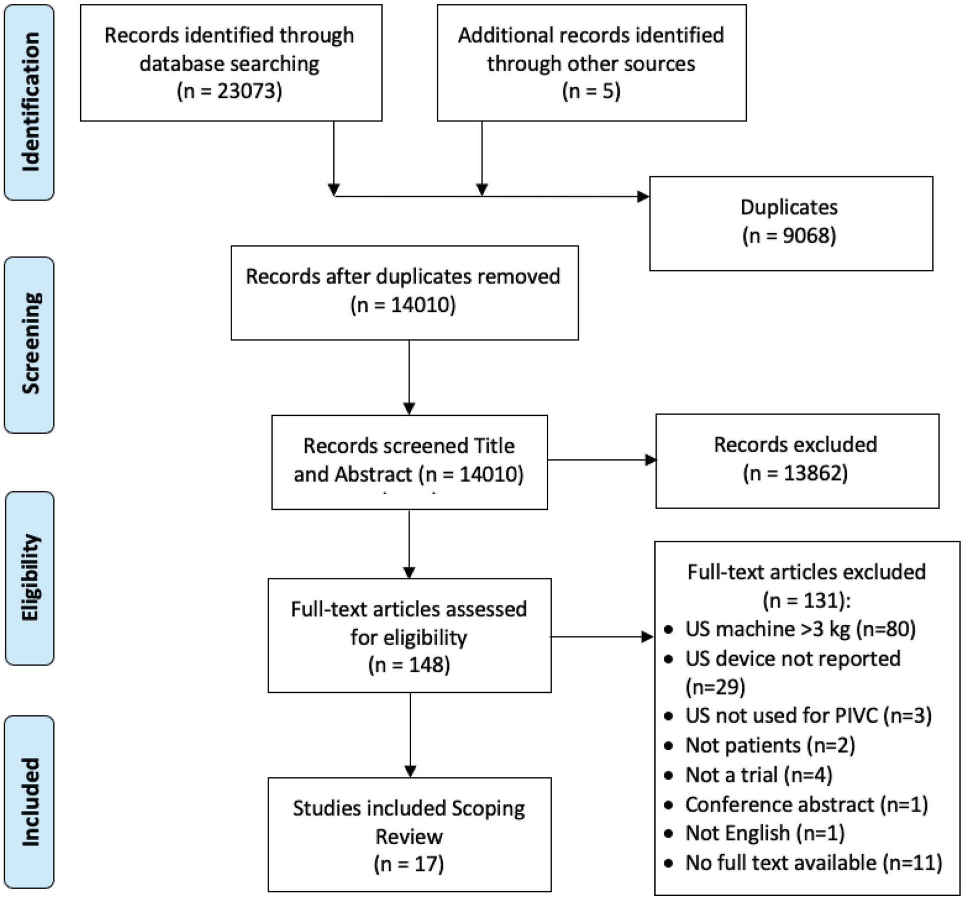

Figure 1 PRISMA flow diagram for scoping study. *Abbreviations: PIVC, peripheral intravenous catheter; US, ultrasound.*

the focus patient population in 15 studies, with pediatrics included in 3 studies.[23,28,34] Clinical populations, where described, included a mix of DIVA (1773 of 5118, 38.7%) and non-DIVA participants (61.3%). Nine studies included patients with DIVA, with a range of definitions provided, including 1 study that used the A-DIVA scale.[36] Ultrasound operators (n = 286) included nurses (71.3%), physicians (8.0%), paramedics (20.3%), and 2 sonographers (0.4%; Table 1). None of the studies that examined ultrasound for PIVC insertion included central venous devices.

Ultrasound Equipment and Insertion Procedures

Seventeen studies provided details of ultrasound equipment brand and model that fit the scoping study inclusion criteria of weight (<3 kg) and portability (Table 1). One study compared the reliability and validity of a handheld tablet-type and a cart-mounted laptop device in assessing vein characteristics and detecting thrombus.[31] Equipment selection regarding price, size, portability, features, or capability was discussed in 2 studies.[27,31]

Six studies compared USG PIVC insertion with standard landmark technique.[22,23,27,30,33,34] Dynamic ultrasound technique (real-time visualization during vessel cannulation) was used in 15 of 17 studies.[10,21,22,24-27,29-36] Static ultrasound technique (visualization of vessels prior to cannulation and marking of the skin insertion point), followed by standard insertion technique, featured in 3 studies.[23,29,33] One study that compared dynamic and static techniques reported more favorable insertion outcomes (first-attempt success, number of attempts per patient, time to insertion) when the static method was used.[33] In another study, doctors used ultrasound static technique to mark the site for the nurses to cannulate.[23] Only 1 study mentioned training nurses in single- and dual-operator technique.[25] Ultrasound probe orientation was described in 9 studies, with short axis (out of plane) used in 6 studies,[10,23,25,29,33,35] long axis (in plane) approach in another,[34] and either technique in 3 studies.[21,22,36] Probe frequencies ranged between 5 and 18 MHz (mean = 7 MHz).

A range of insertion procedural techniques was reported. Skin preparation for insertion predominantly was described as routine skin cleansing as for traditional standard PIVC insertion. Four studies described using a sterile or aseptic technique,[10,24,29,35] with others reporting Aseptic Non Touch Technique (ANTT®) with sterile probe cover and sterile gel,[10,27] skin disinfection swabs and conventional gel,[34] and standard precautions with a nonsterile glove over the probe.[22] One pediatric study placed an acoustic gel ridge between the transducer and the skin.[23] One study used

TABLE 1

Demographics and Reported Outcomes of Included Studies

First Author, Year, Country	Study Design, Duration, Setting	Population (n)	Objectives	US Operator	PIVC Insertion Technique n (%)	USG Device (Weight)	PIVC Insertion Outcomes	Postinsertion Outcomes
Abe-Doi, 2023 Japan[28]	Observational prospective cohort study, 3 mo Hospital ward	31 Adults 33 PIVCs DIVA: 20/39 (51.3%) attempts Non-DIVA: 19/39 (48.7%) attempts	Assess USG for vein assessment, target vein selection, and puncture	2 nurses	Dynamic USG: 16 (48.5%) Static USG: 17 (51.5%) Short axis Sterile technique	Fujifilm Sonosite iViz air (570 g); linear-array (5–10 MHz) 2D probe	*Total USG attempts:* 39 *Overall insertion success:* USG 33/39 (84.6%) Dynamic USG: 16/19 (84.2%) Static USG: 17/20 (85.0%) *1st attempt success:* 85.3% (29/34) *DIVA success:* 84.2% (16/19)	*Mean PIVC dwell time:* USG: 70 (49–99) h *PIVC failure rate:* > 24 h: 3.2% (1/31)
Acuna, 2020 USA[20]	Retrospective review of prospectively collected hospital data, 1 year, Emergency department	483 Adults 444 PIVCs All DIVA, based on physical examination findings or failed PIVC attempt using traditional technique	Evaluate the performance of a handheld USG device for difficult PIVC access	32 nurses and 11 paramedics	Dynamic USG In-plane (long axis) technique: 338/483 (70%) Out-of-plane (short axis) approach: 48/483 (10%) Technique not documented: 97/483 (20%)	Philips Lumify linear ultrasound transducer (135 g); screen not reported	*Overall insertion success:* 92% (95% CI, 89%–94%) *1st attempt success:* 84% (95% CI, 80%–87%) 2nd *attempt success:* 13% (95% CI, 9%–16%) *Insertion site:* Antecubital fossa: 24% Forearm: 23% Upper arm: 30% Unknown: 23% *Insertion complications:* In 396/483 (82%) cases, no complications associated with the IV insertion occurred. No arterial punctures or hematomas occurred *Operator-reported perceptions:* • 84% (95% CI, 80%–87%) stated that the handheld device was adequate to perform USG PIVC access • Approx 80% (95% CI, 76%–83%) reported needle visualization was adequate • 72% (95% CI, 67%–76%) stated image quality was "good" • 76% (95% CI, 71%–80%) reported that Doppler capabilities on the handheld device were adequate • 92% (95% CI, 89%–94%) reported no difficulty navigating the handheld device • On a scale of 1 to 10, the mean confidence level in performing USG PIVC access using the handheld ultrasound device was 8.4 (SD 2.33)	*PIVC complications during hospital stay:* 62/483 (13%) • Occlusion: 16/62 (26%) • Phlebitis: 2/62 (3%) • Infiltration: 24/62 (39%) • Leaking/bleeding: 20/62 (32%) 41/62 (66%) complications occurred within 48 h of insertion

(*continues*)

TABLE 1

Demographics and Reported Outcomes of Included Studies (*Continued*)

First Author, Year, Country	Study Design, Duration, Setting	Population (n)	Objectives	US Operator	PIVC Insertion Technique n (%)	USG Device (Weight)	PIVC Insertion Outcomes	Postinsertion Outcomes
Adhikari, 2010 USA[21]	Retrospective chart review, 12 mo, Emergency department	764 Adults	Compare PIVC infection rates USG vs standard technique	7 nurses	Dynamic USG: 402 (52.6%) 362 (47.4%) Short axis to locate vessel Long axis to access vessel Standard precautions	Fujifilm Sonosite iLook 25 (1.27 kg); probe not described	*Total USG attempts:* Not reported *Antecubital fossa insertion:* Dynamic USG: 19% PIVC: 75%	*Mean PIVC dwell time:* USG: 2.6 d 2.4 d ($P = .03$) *PIVC infection rate:* USG 2/402 (5.2/1000 PIVC) 3/362 (7.8/1000 PIVC) ($P = .68$)
Bair, 2008 USA[22]	Randomized controlled trial, 12 mo, Emergency department	47 Pediatrics (<7 y) All patients had previous failed routine PIVC insertion	Compare static USG vs standard technique for PIVC insertion and venipuncture	6 doctors used USG to locate and mark vessel sites, then nurses (*n* = Not reported) inserted PIVC at marked sites	Static USG: 24 (51.1%) 23 (48.9%)	Fujifilm Sonosite iLook 25 (1.27 kg); 10 MHz linear transducer	*Total USG attempts:* 44 *Overall insertion success:* Static USG: 13/23 (57%) 6/21 (29%) *1st attempt success:* Static USG: 8/23 (35%) 6/21 (29%) *Perceived ease of PIVC insertion ("easy" or "very easy") when cannulation was expected to be "difficult" or "very difficult":* Static USG: 4/18 (22%) 0/17 (0%)	Not reported
Brannam, 2004 USA[23]	Prospective observational study, 5 mo Emergency department	321 difficult-to-stick patients (repeated blind IV placement failure or established history)	Describe the types of patients and success rates for USG-PIVC access by Emergency department nurses	23 nurses	Dynamic USG Axis not reported Aseptic technique	iLook 25, Sonosite (1.23 kg); probe not reported	*Total USG attempts:* 321 *Overall insertion success:* 280/321 (87%) 12/41 (29%) required CVL insertion 9/41 (22%) had external jugular line inserted 20/41 (49%) had successful USG PIVC placement by a second inserter (nurse or physician) *Complications:* 4/321 (1.2%) arterial punctures; No other insertion complications	Not reported
Burton, 2022 Australia[8]	Prospective observational pilot study, 6 wk, Pre-hospital	32 Adults 16 PIVC DIVA: 29/32 (91%)	Investigate intensive care paramedics' ability to use A-DIVA scale and insert USG PIVCs in DIVA patients	44 Paramedics Majority completed <2 procedures; 1 paramedic enrolled >10 patients	Dynamic USG: 32 (100%) Short axis approach encouraged Sterile technique (probe cover, gloves, drape) encouraged	Butterfly using Apple iPad mini tablet screen; probe with microchip	*Total USG attempts:* 32 *Overall insertion success:* 16/32 (50%) *1st attempt success:* 14/16 (87%) *Antecubital fossa insertion: 75%*	Not reported

(*continues*)

TABLE 1

Demographics and Reported Outcomes of Included Studies (*Continued*)

First Author, Year, Country	Study Design, Duration, Setting	Population (n)	Objectives	US Operator	PIVC Insertion Technique n (%)	USG Device (Weight)	PIVC Insertion Outcomes	Postinsertion Outcomes
Chinnock, 2007 USA[24]	Prospective observational study, 13 mo, Emergency department	100 Adults Difficult access defined as at least 2 previous unsuccessful attempts and no other visible vein to use	Determine how choice of vein, reason for difficult access, or 1 vs 2-person technique affected success rate of USG PIVC in patients with difficult IV access	18–20 Nurses 4 nurses accounted for 52/100 attempts	Dynamic USG 1-person technique: 81% 2-person technique: 19% Initial vein chosen: basilic 52%, brachial 34%, antecubital 9%, cephalic 5% (6 patients had no adequate vein for cannulation on ultrasound) Short axis approach	SonoSite iLook 25 (1.23 kg); 7.5 MHz linear probe	*Overall success rate:* 63/119 attempts (53%; 95% CI 44%–62%) *1st attempt success rate:* 52/63 (83%) *Success per vessel type:* Basilic vein: 39/56 attempts (70%, 95% CI 56%–81%) Brachial vein: 7/21 attempts (33%) *No difference in success rates by reason for difficult access* (IV drug use 62%, obesity 62%, multiple prior medical procedures 64%). If patients had 2 or more reasons for difficult access, success rate was 52% *Success rate by technique:* 1-person: 50/76 (66%) 2-person: 13/18 (72%) Success rates of the 4 nurses who did more than half of the sample was 67%, versus 58% for the remainder. Over the study for these 4 nurses, in the first half their success rate was 60%, in the second half it was 74%. For the other 14 nurses, their success rates went down from 67% in the first half to 50% in the second half. *Success rate to get blood (regardless of whether cannulation was successful): 79/100 (79%)* *Complications:* Arterial puncture: 5/100 (5%) Arm numbness: 3/100 (3%) Severe pain: 8/100 (8%) All complications resolved during the Emergency department visit	Cannulation was only considered successful if the catheter remained in place until the completion of therapy.

(*continues*)

TABLE 1

Demographics and Reported Outcomes of Included Studies (*Continued*)

First Author, Year, Country	Study Design, Duration, Setting	Population (n)	Objectives	US Operator	PIVC Insertion Technique n (%)	USG Device (Weight)	PIVC Insertion Outcomes	Postinsertion Outcomes
Galen, 2018 USA[25]	Prospective cohort, 3 mo, 2 Telemetry wards (intervention and control)	40 Adults	1.Test the effectiveness of a USG PIVC service to reduce the number of newly placed central venous catheters (including peripherally inserted central catheters) on an inpatient medical ward 2.Assess the acceptability and perceived benefit of this service by nurses	1 Doctor	Dynamic USG: 40 (100%)	GE V-Scan (436 g); dual probe	*Total USG attempts:* 40 *Reduction in CVC placement:* Intervention ward: 0.47 CVC placed/day Control ward: 0.67 CVC placed/day (*P* = .08) *Nurses' reported perceptions of USG service:* • 93% reported USG PIVC service reduced care delays • 73% reported a lack of USG PIVC service would increase the CVC/PICC insertion rate • 80% reported patients preferred USG to technique • 100% agreed USG service needs to be permanent	Not reported
Kanno, 2020 Japan[29]	Prospective pre–post study, 7 mo including 4-wk preintervention, 4-wk training, 10-wk uptake, 10-wk postintervention, Surgical ward	197 Adults	Developed USG algorithm to enable surgical nurses to acquire USG PIVC skills to standardize technique and prevent failure	23 Nurses	Pre: 54 Post: Dynamic USG: 143	Fujifilm Sonosite iViz air (570 g); 6.4 MHz linear-array transducer	*Total USG attempts:* 143 *1st attempt success:* Pre (Standard): 36/54 (67%) Post (USG algorithm): 91/143 (67%) *Compliance to algorithm:* 23/143 (16.1%)	*PIVC failure:* Pre: 19/54 (35.2%) Post: 48/143 (33.6%) (*P* = .831) *PIVC failure per ITT analysis:* Pre: 146.7/1000 PIVC days Post: 99.9/1000 PIVC days (*P* = .214)

(*continues*)

TABLE 1

Demographics and Reported Outcomes of Included Studies (*Continued*)

First Author, Year, Country	Study Design, Duration, Setting	Population (n)	Objectives	US Operator	PIVC Insertion Technique n (%)	USG Device (Weight)	PIVC Insertion Outcomes	Postinsertion Outcomes
Partovi-Deilami, 2016 Denmark[33]	Prospective pre–post study: Pre (3 mo); USG training and implementation (6 mo); post (4 mo) Mixed setting (inpatients and outpatients)	103 DIVA (pre 33, post 70) Adult and pediatric Inpatients and outpatients with difficult access, defined as failed placement by nurse anesthetists using standard techniques	Evaluate the quality of care at first contact with inpatients with DIVA, before and after implementation of USG PIVC placement by nurse anesthetists	10 Nurse anesthetists provide a 24-h mobile PIVC service for patients with DIVA when nurses and doctors fail insertion	Dynamic USG Recommended 18 gauge and 4.5 cm length in adults. In children, they could choose. Single operator technique Preferential in-plane/long axis view Skin disinfection swabs	Sonosite Nanomaxx (2.7 kg); 5–15 MHz linear probe	*Insertion success:* Pre (Standard): 0/33 (0%) Post (USG): 58/70 (83%) *Procedure time:* Pre (Standard): 20 min Post (USG): 10 min *Median number of attempts:* Pre (Standard): 3 Post (USG): 2 *CVC placement:* Pre (Standard): 34% Post (USG): 7% No change in patient discomfort No adverse events (no arterial puncture nerve involvement, large hematoma or misplacement)	Not reported
Peters, 2022 Australia[31]	Prospective cohort study, 3 mo, Tertiary hospital	102 Adults	To determine the first-attempt cannulation success rate of newly trained USG PIVC inserters with ultrasound using remote supervision and timely written feedback based on app-based screen recordings taken during insertion	14 Junior medical officers (JMO) One JMO did not attempt any USG PIVCs, as patients already had a CVC	Dynamic USG: 102 USG PIVC insertion, video-recorded (100/102), with feedback by USG PIVC experts provided within 48 h	Philips Lumify linear ultrasound transducer (135 g) with Samsung Galaxy tablet	*First attempt insertion:* 72/102 (71%) *Overall procedural success rate*: 83% (85/102) *Patient satisfaction survey* (*78 patients completed) *Patient-reported PIVC insertion difficulty*: mean 7.5/10 *Patient perception of USG PIVC insertion skill:* mean 8.4/10	• *PIVC Complications:* 28/78 (35%) • PIVC failure: 16% (13/78) • Pain on insertion: 9% (7/78) • Bruising: 4% (3/78) • Uncomfortable location: 1% (1/78) *JMO satisfaction* with USG training high

(*continues*)

TABLE 1

Demographics and Reported Outcomes of Included Studies (*Continued*)

First Author, Year, Country	Study Design, Duration, Setting	Population (n)	Objectives	US Operator	PIVC Insertion Technique n (%)	USG Device (Weight)	PIVC Insertion Outcomes	Postinsertion Outcomes
Reeves, 2017 USA[26]	Prospective pre–post cohort study, 48 mo, Med/surg and step-down units	124 Adults	Implement a nurse-led vascular access preservation program using USG to reduce the use of nonessential PICC insertions by 10%, reduce PIVC failure, and improve patient experience	39 Nurses	Pre (Standard): 60 Post (Dynamic USG): 64 Sterile probe cover, sterile gel, aseptic non-touch technique	Bard, BD Site-Rite Prevue (900 g)	*Total USG PIVC insertions over 4 y: 1296* *Mean number of attempts:* Pre 5.5/patient 6-mo post (USG): 1.5/patient *Patient experience of insertion:* qualitative data collected, reported to be positive	*PIVC failure within 72 h of insertion:* Pre (Standard): 75% Post (USG): 34% *Nonessential PICC utilization:* Pre (Standard): 43% Post (USG): 26% *Nonessential PICC-associated bloodstream infection*: Pre (Standard): 16% 1-y post: 14% 2-y post: 6% 3-y post: 0%
Schnadower, 2007 USA[27]	Observational study, Duration not reported; Pediatric emergency department	83 Pediatrics (<7 y)	To determine whether peripheral veins can be detected by US and to determine vein characteristics as measured by US, associated with successful cannulation in young children	Practitioners not specified, blinded to US results	Practitioners clinically assessed vein as standard and marked vein 2 Investigators used US to measure vein and location chosen by practitioners The US pictures later were reviewed by a certified sonographer blinded to the study objectives	Sonosite 180 plus (2.6 kg); 5-10 MHz, hockey-stick 26 mm broadband linear array transducer	• *Total insertion attempts:* 120 • Clinically apparent vein: 90 attempts • Not clinically apparent vein: 30 attempts • US detected all 90 clinically apparent veins and 17/30 veins in the not clinically apparent group • Rate of insertion success: 69% (62/90) for visible or palpable veins • 10% (3/30) for nonvisible and nonpalpable veins • Interrater agreement between investigators and expert sonographer: (k = 0.82, 95% CI 0.66– 0.97)	Not reported

(*continues*)

TABLE 1

Demographics and Reported Outcomes of Included Studies (*Continued*)

First Author, Year, Country	Study Design, Duration, Setting	Population (n)	Objectives	US Operator	PIVC Insertion Technique n (%)	USG Device (Weight)	PIVC Insertion Outcomes	Postinsertion Outcomes
Scoppettuolo, 2016 Italy[34]	Retrospective analysis, 12 mo, Emergency department	76 Adults, "difficult" superficial veins, (absence of visible and/ or palpable vein of the arms or failure of 2 or more venipuncture attempts)	Describe experience with Seldinger technique to insert long PIVCs	Nurses or physicians	Dynamic USG and direct Seldinger technique Short axis (out-of-plane) Sterile procedure (drape, gel, probe cover)	Sonosite Nanomaxx (2.7 kg); 5–10 MHz linear probe	100% of catheters were successfully inserted without complication *Mean number of attempts:* 1.57 ± 0.63 *Mean insertion time:* 9.5 ± 2.27 min	55/76 (73%) of patients had long PIVC electively removed after 7–8 d and replaced by CVC 21 patients (27%) had catheter removed for end of use; the mean duration was 2.33 ± 2.95 d (range 2–6 d) No major infective or thrombotic complications were reported No accidental dislocation occurred
Skulec, 2020 Czech Republic[32]	Randomized controlled trial, 12 mo, Pre-hospital, First emergency response	300 Adults	Compare Dynamic & Static USG PIVC insertion with PIVC insertion in pre-hospital emergency settings	3 Paramedics 2 Doctors	Dynamic USG: 100 (33.3%) Static USG: 100 (33.3%) Standard PIVC: 100 (33.3%)	GE V-Scan dual probe (436 g)	*Total USG attempts:* 200 *1st attempt success:* Dynamic USG: 88% Static USG: 94% PIVC: 76% ($P < .001$) *Number of attempts per patient:* Dynamic USG: 1.20 ± 0.57 Static USG: 1.07 ± 0.29 PIVC: 1.45 ± 0.90 ($P < .001$) *Time to insertion (seconds):* Dynamic USG: 75.3 ± 60.6 Static USG: 43.5 ± 26.0 PIVC: 82.3 ± 100.9 ($P < .001$) *Local complications from the procedure:* • *Local pain:* Dynamic USG: 4% Static: 3%: 16% ($P < .001$) • *Extravasation:* Dynamic USG: 8% Static: 3% 10% ($P = .136$) • *Cannulation of artery:* Dynamic USG: 0% Static: 1% 0% ($P = .367$) • *PIVC dislodgement:* Dynamic USG: 1% Static: 0%: 0% ($P = .367$)	Not reported

(*continues*)

TABLE 1

Demographics and Reported Outcomes of Included Studies (*Continued*)

First Author, Year, Country	Study Design, Duration, Setting	Population (n)	Objectives	US Operator	PIVC Insertion Technique n (%)	USG Device (Weight)	PIVC Insertion Outcomes	Postinsertion Outcomes
Takahashi, 2019 Japan[30]	Observational study, 1 mo, Medical	21 Adults 26 PIVCs 2 images each (n = 56)	Compare tablet-type US device versus cart-mounted US device by assessing vein diameter and depth for catheter site selection and/or detecting causes of catheter failure	A trained research nurse inserted the PIVCs, which were then checked by a sonographer	Dynamic USG: 26 (100%)	Fujifilm, SonoSite iViz (570g), 6.4 Mhz linear-array transducer Noblus, Hitachi (9 kg), 5-18 Mhz linear-array transducer (Cart-mounted)	*Total USG attempts:* 26	*Intrarater reliability: ICC (95% CI)* Vein diameter: 0.92 (0.57–0.98) Vein depth: 0.78 (0.10–0.95) *Interrater reliability: ICC (95% CI)* Vein diameter: 0.95 (0.78–0.99) Vein depth: 0.94 (0.77–0.90) *Validity: Pearson's* r Sonographer: Vein diameter: 0.83 ($P = .01$) Vein depth: 0.77 ($P = .02$) Nurse: Vein diameter: 0.70 ($P = .01$) Vein depth: 0.64 ($P = .01$) *Detection of IV thrombus and subcutaneous edema:* No significant differences in criterion-related validity or interrater and intrarater reliability were detected
van Loon, 2022 Netherlands[35]	Prospective observational study, 9 mo, Multicenter (Site 1: pre-operative area; Site 2: oncology ward; Site 3: radiology department)	1855 USG PIVC procedures in adults A-DIVA scale: Low risk (68%) Mod risk (23%) High risk (9%)	Quantify the number of USG PIVC insertions novices need to become competent	49 nurse anesthetists, PACU nurses, oncology nurses and radiographers	Dynamic USG 1-person Short axis or long axis viewing technique	Philips Lumify linear transducer (135 g)	38/49 (78%) staff achieved competency within 40 procedures; 11 (22%) staff did not achieve competency Mean number of USG PIVC procedures needed to achieve competency = 34 (minimum of 21) Time to successful cannulation decreased with experience ($P < .001$)	Not reported

Abbreviations: A-DIVA, Adult Difficult Intravenous Access scale; CI, confidence interval; CVC, central venous catheter; g, grams; h, hours; ICC, intraclass correlation; kg, kilograms; min, minutes; mm, millimeters; mo, month/s; PACU, post anesthesia care unit; PIVC, peripheral intravenous catheter; PICC, peripherally inserted central catheter; sec, seconds; US, ultrasound; USG, ultrasound-guided.

antiseptic solution instead of gel,[29] and another used bacteriostatic lubricant following routine skin preparation and inserted the PIVC through the gel, without removing the gel prior to insertion.[22] Only 1 study reported using an ultrasound probe cover, and sterility details were not included.[29] Another study described postprocedure equipment cleaning using germicidal wipes.[27] No studies discussed the maintenance, disinfection, and storage requirements of handheld ultrasound machines.

Two studies examined interrater agreement. In 1 study,[28] practitioners used landmark technique to mark the preferred vessel, then 2 investigators used ultrasound to measure vessel characteristics, and the ultrasound images were later assessed by an expert sonographer. In another study,[31] postinsertion interrater reliability, including vessel depth, diameter, and detection of thrombus or subcutaneous edema, was calculated between a trained research nurse and sonographer.

PIVC Insertion Outcome Measures

A total of 5118 PIVCs were inserted via ultrasound in 4576 patients (4446 adults, 130 pediatrics) across 17 studies; 1 study[34] included 91 PIVCs but did not specify the number of patients. Ten studies[10,21,23-25,28,29,32,34,35] reported overall success rate (mean = 75.5%, standard deviation [SD] = 17.6), and 9 studies[10,21,23,25,29,30,32,33] reported first insertion success rate (mean = 75.4%, SD = 18.2). Other insertion outcomes included mean attempts,[32-35] insertion procedure time,[33-36] complications during insertion,[21,24,25,34] compliance to the algorithm,[30] interrater agreement of ultrasound findings,[28,31] and mean number of ultrasound procedures needed to achieve competency.[36] Postinsertion outcomes included PIVC complications,[21,25,32,33,35] failure rates,[27,29,30] infection,[22] mean dwell time,[22,29] and need for other vascular access device (Table 1).[24,26,27,34]

Seven studies described vessel selection based on depth and diameter,[28-32,34,35] while others recommended the widest vein visible up to 1 cm below the skin surface[33] or "closest to the skin."[22] Postinsertion sites and vessel characteristics, including depth, diameter, and presence of intravenous thrombus or subcutaneous edema, were investigated for intrarater and interrater reliability outcomes between a tablet-type and laptop-type device; however, the raw data were not reported.[31] One study found no significant improvement in the incidence of catheter failure following the introduction of an algorithm using USG PIVC placement; compliance to the algorithm was low (16%).[30] Four studies reported that implementation or expansion of a USG PIVC program led to a reduction in the use of more invasive vascular access catheters.[24,26,27,34]

Education Strategies and Competence

Ultrasound PIVC insertion expertise was described as *novice*, *experienced*, *competent*, or *trained*, with most studies reporting this criterion. Participants with little or no prior ultrasound experience participated in 9 studies,[23-25,27,30,32,34,36] experienced ultrasound users featured in 5 studies,[21,22,26,29,35] and other studies included a mix of providers with various levels of ultrasound experience.[10,31,33] Ultrasound experience was determined by either the total number of USG PIVC insertions during a clinician's career[29,33] or the years of experience inserting PIVCs with ultrasound.[22] Four studies did not define ultrasound experience (Table 2).[10,21,26,35]

Among the 17 studies reviewed, 12 described the ultrasound PIVC training program or provided some details on the training adopted for the study.[10,21-25,27,30,32-34,36] Three studies with experienced ultrasound users did not require further ultrasound training,[26,29,35] and 2 studies required no specific training in USG PIVC insertion, as this was not the focus of the study (Table 2).[28,31]

Initial ultrasound training programs ranged from 1 to 12 hours, consisting of a variety of learning strategies, including e-learning, didactic sessions, and instructional videos on vascular anatomy, vein characteristics, vessel location and assessment, aseptic nontouch technique, and identification of complications. Ultrasound teaching focused on knobology (manipulation of ultrasound knobs and system controls to obtain optimal images), physics, equipment applications, ultrasound PIVC insertion techniques (short and long axis), vein visualization, needle guidance, image interpretation, and other assistive devices (such as near-infrared devices) to facilitate insertion success. Theory sessions were generally followed by practice in simulated settings on gelatin phantoms (training models). One program included training in 1-person and 2-person technique.[25]

Following the training program, competency was defined by successful insertion of a minimum number of USG PIVCs, either self-reported, observed, or assessed by preceptors or experts. This ranged from successful insertions on phantoms progressing to between 1 and 10 successful insertions in patients. One study provided an ultrasound algorithm for nurses to follow, but compliance with the algorithm was reportedly low, which the authors attributed to nurses being time-poor.[30] Another study featured a performance checklist comprising 29 elements and an audit tool, with an additional requirement being that the nurses had to achieve 3 successful USG PIVC insertions per month to maintain competency.[27] A multicenter prospective observational study investigated how many USG PIVC insertions were needed to achieve competency, noting that first-attempt cannulation success dramatically increased with more experience, with a mean of 34 procedures per practitioner to become competent.[36] However, other studies did not report how USG PIVC competence was measured.

Patient and Clinician Perspectives

Five studies reported clinician or patient perspectives as a secondary outcome.[21,23,26,27,32] The total number of patients included in these studies was over 800, with over 100 staff. However, none of the studies focused predominantly on clinician or patient perspectives, and most studies

TABLE 2

Baseline Experience Levels of Inserters and Ultrasound Training Reported

First Author, Year	Inserters	Prior USG Skills or Expertise	Training Program	Training Time Total	Competency Measure Other Comments
Abe-Doi, 2023[28]	2 Nurses	Experienced USG PIVC (>100)	Not required	Not reported	Not reported
Acuna, 2020[20]	32 Nurses 11 Paramedics	Competent USG (not defined)	4-h teaching session including a lecture and hands-on training practising USG PIVC placement using phantoms (training models) Followed by 8-h session (lecture and hands-on practice) on how to use US device	12 h	A minimum of 6 supervised USG PIVC placements
Adhikari, 2010[21]	7 Nurses	Experienced USG PIVC (87% had >1 y experience)	Lectures on USG physics and PIVC insertion techniques; videos of USG guidance during PIVC placement; demonstration; and hands-on practice with phantoms	2 h	5 supervised USG PIVC insertions
Bair, 2008[22]	6 Doctors used US to locate and mark vessel sites, then nurses (n=Not reported) inserted PIVC at marked sites	Varied No previous knowledge assumed	Use of USG equipment and concepts related to peripheral vein visualization and identification, and accurate skin marking	1 h	Provide sufficient instruction to be realistic in a "real world" setting but not to create ultrasound expertise
Brannam, 2004[23]	23 Nurses	Novice USG	45-min lecture included still images, video segments, and USG physics and technique explanation, followed by hands-on practice on an inanimate model simulating a deep peripheral arm vein.	Not reported	Not reported
Burton, 2022[8]	44 Paramedics	Novice USG 86% Experienced USG (not defined) 14%	Vascular access and lung USG 30 min online then face to face mapping on each other followed by practice on phantoms. Foundational USG concepts, physics, USG vascular access techniques followed by practice on phantoms Training was conducted by an external ultrasound training agency and facilitated by experienced sonographers	2.15 h	Not reported Only 14/44 (31%) Paramedics attempted USG PIVC after training
Chinnock, 2007[24]	18 Nurses (another part says 20)	Novice USG	90-min training session: didactic lecture, hands-on use of US machine, USG cannulation of phantom Trained in short axis approach only. Trained in both 1-person technique and 2-person technique.	90 min	Not reported
Galen, 2018[25]	1 Doctor	Experienced USG (not defined)	Not required	Not reported	Not reported

(continues)

TABLE 2

Baseline Experience Levels of Inserters and Ultrasound Training Reported (*Continued*)

First Author, Year	Inserters	Prior USG Skills or Expertise	Training Program	Training Time Total	Competency Measure Other Comments
Kanno, 2020[29]	23 Nurses	Novice USG > 1-y standard PIVC insertion experience, defined as: Beginner: <100 Intermediate: 100–800 Expert: >800	Workbook, e-learning, training lectures, and training practice Principles and basic knowledge of USG, probe techniques, and USG image interpretation	Not reported	Completion of training
Partovi-Deilami, 2016[33]	10 Nurse anesthetists	Novice USG	1-h lecture: basic USG physics, anatomy of the vessels of the arm, techniques for USG PIVC placement (in plane/long axis, out of plane/short axis), and complications 1-h demonstration: USG equipment and hands-on exercises in locating specific veins (cephalic, brachial, basilic, and cubital) performed on each other 1-h practice: USG PIVC placement on gelatin phantoms After basic skills had been acquired, participants performed 3 supervised USG PIVC placements on patients who were under general anesthesia and scheduled for elective surgery	3 h + 3 mo developing skills on patients	3 mo after the training, participants were given a test encompassing 12 questions and performed 1 supervised USG PIVC procedure
Peters 2022[31]	14 Junior medical officers	No formal ultrasound qualification; and had performed <5 previous USG PIVC insertions	1-h Self-directed USG PIVC online theory 2h Face-to-face simulated practical training session Orientation to the study aims, protocol, patient recruitment and consent • Introduction to using the ultrasound device and tablet as well as storage and access • Simulation-based practical training on vascular access simulators	3 h	Face-to-face: each participant was required to perform 1 mock patient encounter and demonstrate USG PIVC insertion on a gel phantom with sign off by a study investigator Remotely supervised practice: Requirement of a minimum of 5 insertions and successful insertion in at least 3 patients to be able to practice independently
Reeves, 2017[26]	39 Nurses	Novice	1-h online module on technical aspects of the USG device, then 8 h face-to face instruction, then 12 h clinical practice Principles of vascular access, anatomy and physiology, aseptic non-touch technique, insertion site selection, ultrasound technology, clinical reasoning, complication identification and management, psychomotor skills	9 h	Competency demonstrated by completing a performance checklist consisting of 29 elements Required 3 USG PIVC insertions/month to maintain competence
Schnadower, 2007[27]	Emergency department practitioners	No	Not applicable (all PIVCs were inserted by landmark technique and position checked with US)	Not applicable	Not applicable

(*continues*)

TABLE 2

Baseline Experience Levels of Inserters and Ultrasound Training Reported (*Continued*)

First Author, Year	Inserters	Prior USG Skills or Expertise	Training Program	Training Time Total	Competency Measure Other Comments
Scoppettuolo, 2016[34]	Emergency department nurses or physicians	Experienced USG (not defined)	Not required	Not reported	All staff previously had undergone extensive training in USG insertion of different venous-access devices (PICCs, midline catheters, and peripheral cannulas)
Skulec, 2020[32]	3 Paramedics 2 Emergency physicians	*Paramedics:* Novice USG, but PIVC >1000 *Physicians:* Experienced in both >500 and USG >200	*Paramedics:* Day One: 4 h didactic presentations (general principles of point-of-care US) 4 h hands-on session with healthy volunteers (1:5 instruction) Day Two: 2 h instruction (detailed anatomy, operation of portable US device, dynamic and static techniques) and 2 h USG PIVC practice on gel phantoms and on each other (1:2 instruction) *Physicians:* Not applicable	12 h over 2 d	*Paramedics:* 5 static USG PIVC and 5 dynamic USG PIVC, supervised by a physician investigator
Takahashi, 2019[30]	1 Sonographer 1 Trained research nurse	Sonographer: >10 y experience Nurse: Not reported	Not reported	Not reported	Not reported
Van Loon, 2022[35]	49 nurse anesthetists, post-anaesthesia care nurses, oncology nurses and radiographers	Novice USG Competent and qualified in Standard PIVC Employed on site 3 or more days/week	2 wk theoretical training: included pretest; readings with US background and theory; 1 h face-to-face lecture; post-test; followed by hands-on training (traced veins on a life model, then 15 cannulations on phantoms) 4 wk supervised life-case training: Participants were required to perform at least 40 USG procedures on patients, with both short-axis and long-axis viewing technique; experienced clinicians provided direct supervision and feedback for the first 10 procedures	6 wk	Data regarding 40 USG PIVC per participant (successful first attempt, number of attempts needed to perform a successful procedure, time needed to perform cannulation successfully, used USG technique, patient-related data) were registered in the participant's logbook and used for analyses to determine competency

Abbreviations: d, days; h, hours; min, minutes; mo, months; PIVC, peripheral intravenous catheter; US, ultrasound; USG, ultrasound guidance; wk, weeks; y, years.

did not report the actual number of staff or patients who provided their perspectives of the US technology.

Patient perspectives on handheld point-of-care ultrasound for PIVC insertion included reports of decreased pain and active requests for USG PIVC insertion in the studies that reported patient viewpoints.[27,32] However, nurse anesthetist inserters, in a study that included adult and pediatric inpatients and outpatients with DIVA, perceived no change in patient discomfort with USG compared to standard PIVC insertion technique 3 months after their initial ultrasound training (Table 1).[34]

Five studies mentioned clinician perspectives on handheld point-of-care ultrasound for PIVC insertion[21,23,26,27,32]; these also indicated positive opinions on ultrasound and its adoption within clinical areas. One study identified high levels of satisfaction in a feedback survey among junior medical doctors who completed the ultrasound training program with remote supervision.[32] Operator perceptions of the ultrasound device featured in 2 studies.[21,23] In a study comparing static technique to standard landmark insertion in pediatric DIVA patients, nurse participants reported ease of venipuncture in 4 of 18 (22%; 95% CI, 6%-48%) cannulations in the ultrasound group to be "easy" or "very easy" despite initial vessel assessments of "difficult" or "very difficult," compared to 0 of 17 cannulations (0%; 95% CI, 0%-20%) in the standard group.[23] In another study, nurses and paramedics completed an online questionnaire about their experience (needle visualization, image quality, Doppler capabilities, navigation, confidence level) each time they used the handheld ultrasound device to attempt PIVC access; over the course of a year, 429 (88%) of 483 cases had a questionnaire completed, with positive results for all indicators (Table 1).[21]

The importance of clinical reasoning when assessing patient vascular access needs and the value of ultrasound availability for patients with DIVA was identified.[27] Another study, in which a doctor performed all of the USG cannulations, found that nurses strongly favored a service providing USG for PIVC insertion, perceiving benefits to patients.[26] In a follow-up survey after the service was introduced, 93% of nurses indicated that the service prevented delays in patient care; 73% reported that if the service were not available, a central venous catheter would have been required for the patient; and 100% agreed that the service should be permanently available on their ward.[26]

DISCUSSION

In this scoping review, 17 studies detailing the use, outcomes, and perceptions associated with compact ultrasound devices for PIVC insertion were identified. Ultrasound-guided technology for PIVC insertion has been adopted by many inserters and institutions globally, and it is now recommended by the Infusion Nurses Society as best practice for patients with DIVA.[37] Bulky and expensive ultrasound machines have often been rationed to use in specialty areas, but the miniaturization of ultrasound provides scope for greater adoption of this technology across the range of settings where PIVCs are inserted.

Study Characteristics

While single hospital sites have dominated the research to date, multisite studies may afford diverse experiences, larger recruitment, increased generalizability, external validity, high scientific rigor, and reliability to transform clinical practice and inform ultrasound PIVC policies and guidelines.[38] Greater portability and miniaturization of ultrasound devices afford investigation on their use and benefits for PIVCs in prehospital and nonspecialty areas. Adoption of this technology into prehospital, hospital-in-the-home, older adult care, general practice, community, and regional and remote settings warrants further investigation. Eight studies (47%) were conducted in general medical-surgical settings, which may correlate with increasing availability and more affordable devices.[27]

Only 3 studies included pediatrics[23,28,34]; yet this population presents unique physical and psychological challenges with PIVC insertion, given their smaller anatomy and low cooperation. Challenges in managing devices, securing and stabilizing insertion sites, and simultaneously inserting the PIVC may explain this paucity. Furthermore, a much higher skill is required for smaller vessels ranging between 0.05 and 3.07 mm.[39]

Studies were limited to higher-income regions. No studies were conducted in lower-resourced regions or countries with predominantly darker skinned populations, where inserters may face challenges using visualization technique alone. The contribution of skin tone to PIVC insertion success or failure is an underresearched area. Access to expensive ultrasound machines may be challenging in lower resourced countries and regions; therefore, more affordable compact ultrasound devices may provide a solution.

Ultrasound Equipment and Insertion Procedures

To the authors' knowledge, this is the first review to focus on miniaturized ultrasound technology for PIVCs; identifying studies that focused on these machines was a challenge. Even in the included studies, few authors reported device size, weight, portability, or mode of transport to the patient. A wide variety of ultrasound equipment featured in the included studies; yet, no studies provided a reason for using the smaller devices, and only 1 study compared device performance with standard ultrasound equipment.[31] Information regarding equipment features, usability, acceptability, value, and efficacy is needed for informing purchase decisions. With more clinicians and organizations looking to adopt or embed ultrasound into PIVC practice, authors should clarify differences between devices. Interestingly, the effects of probe shape (linear or hockey stick), frequency, and footprint on image quality or insertion success were not investigated in any of the studies using compact devices, despite these features being critical for image quality. Furthermore, it would be worthwhile to investigate the relationship between image quality and insertion success rates. Although insertion axis was reported in 8 (47%) of the studies, the effect of probe orientation on PIVC insertion success using smaller devices was not investigated.

Most studies adopted dynamic, real-time technique; 3 used static technique. In the study that compared dynamic and static ultrasound with standard insertion technique in a prehospital setting, the static technique of locating suitable vessels prior to standard insertion technique was described as both "simpler" and "superior"[33]; this warrants further investigation. With compact ultrasound devices, vessel assessment using static technique could be easily incorporated into PIVC training programs, prompting a "look before you stick" approach.

One pediatric study, in which the doctors visualized the vein with ultrasound, then marked it for the nurses to cannulate, reported using "an acoustic gel ridge between the transducer and the skin" to improve vein visualization in limited anatomical space.[23] Dual-operator technique, with 1 person controlling, manipulating the probe, and stabilizing the site, while the other person inserts the PIVC may be an option. Given the complexity of probe positioning and real-time insertion, ultrasound screens attached to the inserter's wrist or probes with screens should be explored, particularly for single-user technique.

From an infection prevention perspective, clarity is needed on skin preparation technique, necessity for sterile gloves and ultrasound probe covers, and procedure for disinfection of the ultrasound probes and devices after each use. In addition, guidance is lacking on device maintenance and secure device storage.

PIVC Insertion Outcome Measures

Seven studies described vessel selection based on depth and diameter; future research should be conducted to identify if such vessel properties impact catheter survival. No studies reported catheter-to-vein ratio. With nearly 50% of PIVCs failing postinsertion,[40] ultrasound examination of vessel characteristics, in conjunction with PIVC type, material, size, catheter length, length in vessel, and catheter-to-vein ratio is critical. Using ultrasound to inform vessel choice, assist PIVC placement, and evaluate postinsertion catheter position and tissue irritation could ensure optimal placement, which would improve catheter survival and reduce complications and early failure.[31] The value of ultrasound in detecting preventable causes of PIVC failure and guiding early removal to prevent complications should also be explored. Ultrasonography was used in 1 study[31] to assess interrater reliability in assessing thrombophlebitis with a tablet ultrasound and a cart-mounted model; however, no thrombophlebitis was detected in the study. Previous studies have reported using larger ultrasound machines to assess thrombophlebitis in extant PIVCs,[5,41] but it would be helpful to know if compact ultrasound devices are efficacious for this purpose.

Education Strategies and Competence

The reporting of ultrasound skills, education, teaching, and learning strategies varied considerably among studies in this review. Providing ultrasound training and maintaining competency among clinicians inserting PIVCs, particularly in DIVA populations, is a priority. Most training programs incorporated some didactic component, followed by simulated cannulation on gel phantoms, and then real-life practice on patients. One study reported a remotely supervised ultrasound training program.[32] Other USG PIVC training strategies featured in the literature that hold promise include artificial intelligence vessel image interpretation,[42] immersive virtual reality,[43] peer-assisted learning,[44] and clinician rotations to the hospital vascular access team.[45]

Achieving competence with USG PIVC insertion is an area that needs more research, particularly as the studies in this review reported a wide range of successful cannulations needed for minimal competency. Included studies used a competence checklist[27] and an algorithm[30] with variable outcomes. Longer-term maintenance of USG PIVC insertion competency was not detailed by any studies. One of the included studies required 3 insertions per month[27]; other authors have suggested that 10 insertions per year are required to maintain proficiency.[46] Another method of competency assessment reported in the literature is hand motion analysis, but further work is needed.[47] Video recording of insertion and postinsertion assessments could be valuable for assessing competence and providing an objective view of success, reducing examiner bias. It may also provide a powerful learning and teaching platform.

Clinician and Patient Perspectives

With growing numbers of patients experiencing difficult cannulation, USG PIVC insertion should be more broadly available. In the 2 studies reporting patient perspectives, feedback was positive,[27,32] which is consistent with published literature.[48-50] Patients with difficult access featured in over half of the studies, yet clinician perspectives of the portable ultrasound technology were rarely reported. In 1 study, nurses and paramedics in the emergency department had positive perceptions of the equipment and its effect on their confidence.[21] One study found that nurses perceived PIVC insertion in pediatric patients with difficult access was easier than expected, but the sample size was small.[23] The only other study to report nurses' perspectives was after the implementation of a doctor-led USG PIVC service; not surprisingly, nurses believed the service reduced care delays and alleviated the need for escalation to more invasive central venous access devices.[26]

Future studies should explore the use of portable ultrasound devices in outpatient clinics and hospital-in-the-home care. It would also be helpful to compare user perspectives and PIVC insertion success rates of larger cart-mounted models with smaller handheld or pocket devices. As nurses are responsible for the majority of PIVC insertions, their perspectives on this technology would be highly valuable, and patient perspectives are also sorely needed.

Implications for Policy/Practice/Research

Ultrasound adoption for PIVC insertion and maintenance will continue to expand in the coming decade, particularly with the increase in more portable, affordable devices. This demands a structured, methodical, and orderly introduction, teaching, and adoption to ensure standardized uptake of the new technology. Clear policies, procedures, guidelines and research regarding device ownership, device management and storage, patient consent, confidentiality, data security, software licenses, and infection control procedures need to be urgently addressed. The lack of standardization regarding the use of sterile versus nonsterile probe covers, equipment cleaning, and decontamination between patients may create infection-related problems as technology uptake increases and more data on ultrasound PIVC infection rates become available.[51]

Benefits of the lightweight devices include being less expensive and easier to carry for clinicians, but evidence supporting their equivalence in vessel visualization to cart-mounted models is lacking. As technology advances, clinicians and researchers should engage in robust research comparing performance and publish their findings. Unlike the stethoscope, ultrasound is technically challenging, and expertise with this technology demands specialized skills and training. More research and evidence for safe, standardized implementation is also needed. Education programs with reliable teaching methods, applicable content, and simulated learning and teaching are essential.

The progression of ultrasound novice to proficient user should also be examined, with more research into skill development. For instance, there may be benefits in commencing ultrasound training using the static insertion method and then progressing to the dynamic method, rather than teaching the dynamic method as the primary technique. Some may perceive the dynamic method as most valuable, while others may consider a natural progression from simple static assessment to more complex real-time insertion as more beneficial[52]; evidence is lacking, and further investigation would be welcome. Operator factors, such as single versus dual operators and the effect on teaching, learning, and insertion success should also be more extensively explored.

Gaps in both research and clinical use for ultrasound currently exist.[53] Compact, portable ultrasound devices could be useful in home care and out-of-hospital settings, such as emergency transportation by ambulance, but more research is required in these settings.[30,31] As ultrasound equipment becomes more variable in price, size, weight, and dimensions, clear classifications and definitions need to be specified. Device durability, image quality, data storage capacity, wireless connectivity, and image transfer vary considerably between ultrasound models and will undoubtedly continue to be upgraded and improved.[13] More comparative studies between different platforms and models are required to determine reliability, usability, and acceptability by clinicians and patients.

Point-of-care handheld ultrasound could also have value for PIVC auditing, research, and competency assessment.[31] Universal consensus regarding the value of ultrasound for vessel assessment pre- and post-PIVC insertion is required. Given the large volumes of PIVC insertions, the prevalence of DIVA, and high rates of PIVC failure globally,[5] more research relating to PIVC insertion using portable ultrasound devices is needed. With smaller, more affordable, and more accessible ultrasound devices, there is no longer the need to rely on suboptimal traditional techniques that have resulted in up to 49% of first insertion and 75% postinsertion failures.[5]

STRENGTHS AND LIMITATIONS

This is the first scoping review, to the authors' knowledge, on the use of compact ultrasound devices for PIVC insertion. This review assisted with the classification of ultrasound equipment, based on weight and mode of transportation to the bedside and point of care. The classification will create clarity for clinicians and researchers when assessing results and efficacy and assist with decisions for purchase and adoption. This scoping review focused on ultrasound equipment weighing ≤3 kg; however, the weight of most devices was not explicitly reported, and dimensions were retrieved from product information sheets available online. Studies reviewed were limited to English due to the authors' lack of academic fluency with other languages. The literature identified may be subject to publication bias, whereby evaluations with less favorable results are less likely to be published than those with positive findings.

CONCLUSION

The increasing availability and affordability of compact handheld or hand-carried ultrasound devices will lead to an expansion in their use in the coming decade. Improved access to ultrasound capability across inpatient and outpatient settings could improve PIVC insertion success and reduce postinsertion failure, particularly for patients with DIVA. However, this review has identified that more research into their use and functionality for PIVC insertion and maintenance is required.

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