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Research paper

Evaluating an ultrasound-guided peripheral intravenous cannulation training program for emergency clinicians: An Australian perspective

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ABSTRACT

Objective: The primary objective of this study was to identify the proportion of clinicians using ultrasound guidance (USG) to insert peripheral intravenous cannulas (PIVCs) in the emergency department (ED) following attendance at a hospital-based USG PIVC training program.
Methods: Over 12-months, USG cannulation training sessions were offered to nurses and doctors competent in standard PIVC insertion (landmark technique), working in the ED. Surveys pre and post-training captured participants' self-reported confidence with cannulation and USG cannulation using a 5-point Likert scale. Supplemental data from observation periods before and after the trainings assessed departmental cannulation practices overall. Data were analysed using descriptive statistics and associations analysed using chi-square tests.
Results: Overall, 195 participants attended training; 58% completed follow-up surveys. Forty-three percent reported using USG cannulation the following month. The median confidence score amongst workshop participants increased from 1 to 3 ($p < .001$). Post-implementation, use of USG cannulation increased from 0.7% to 6.0% post-training ($p < .001$), although the overall number of attempts at PIVC placement did not change.
Conclusions: USG cannulation training increased this practice in the short-term. However, no significant difference in the number of attempts was observed. Further investigation in controlled settings is needed to inform the widespread implementation of USG cannulation training packages.

Introduction

Peripheral intravenous catheters (PIVCs) are the most commonly used intravascular device in the emergency department (ED). Twenty-six percent of patients presenting to the ED require the insertion of a PIVC to facilitate diagnostic investigations and medical treatment such as antibiotics [1,2]. Despite the ubiquity of this procedure, PIVC insertion is often difficult with up to 26% of patients requiring multiple insertion attempts or 'skin pricks' to achieve successful cannulation [2–5]. PIVC insertion failure carries significant clinical implications including investigation and treatment delays, negatively effecting departmental patient flow and wasting scarce healthcare resources [3,6,7]. PIVC insertion failure also contributes to significant patient harm, with repeat insertion attempts associated with greater procedural pain and anxiety, and increased risk of healthcare acquired infection (e.g. *staphylococcus aureus bacteraemia*) [3,8].

Approximately one-third of adults presenting to healthcare facilities have difficult intravenous access (DIVA) [9], a condition characterised by non-visible or palpable veins [10,11]. A number of factors have been identified as predictors of DIVA and subsequent PIVC insertion failure in ED [10–12]. Patient factors such as: age (extremes neonate or geriatric), size (BMI < 18.5 or >30), limited suitable veins, previous history of failed attempts, intravenous drug use, cancer diagnosis, recent chemotherapy, sickle cell disease, patient anxiety and recent hospitalisation or ED visit within 90 days [2,5,6,8] contribute to PIVC insertion failure and substan-

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tial patient harm. Clinician factors also play a role in first attempt PIVC insertion success. Internationally, 80% of PIVCs are inserted by nurses, however in Australia 80% are inserted by physicians [13], many junior. A recent cohort study of 879 ED patients found first attempt insertion success was positively influenced by clinician confidence ($p < 0.0001$) and insertion experience (301–1000 vs <301: OR 1.54, 95% CI 1.02–2.34; >1000 vs <301: OR 2.07, 95% CI 1.41–3.04; $p = 0.0011$) [12]. This is an important consideration for health systems and policy makers as PIVC insertion is typically entrusted to junior physicians and registered nurses, who may not have the PIVC insertion experience to ensure insertion success in DIVA patients.

Historically, in the absence of visible or palpable veins, landmark technique was utilised to guide PIVC insertion; however reported ED first attempt insertion rates remained sub optimal [13]. Ultrasound guided (USG) PIVC insertion has since been demonstrated to increase first attempt insertion rates and reduce the complications associated with blind puncture and multiple attempts. A recent meta-analysis (8 trials; 1660 patients) [14] found the odds of first attempt insertion success more than double using USG compared to blind puncture (odds ratio 2.49; 95% confidence interval 1.37–4.52, $p = 0.003$). Furthermore, USG technique led to a reduced number of attempts, time to cannulate and improved patient satisfaction.

Despite its promise for improving PIVC insertion success in patients with DIVA, there is a learning curve to applying USG techniques. However, physicians, nurses, and non-medical, non-nursing staff can be trained to use ultrasound-guided cannulation with good success [8,15,16]. Once trained however there is no difference in success rates between doctors, nurses or technicians, although success increases with experience [15–17]. Observational studies suggest an 88% first attempt insertion rate is achievable after 15–26 PIVC insertions, while proficiency (70% success rate) is achieved with more than four insertions [18]. Currently there is limited investigation regarding the retention of USG skills and training in ED clinicians. Further, it is not understood the impact training in USG PIVC has on clinician confidence, continued use of USG PIVC practices and departmental cannulation practices.

The primary objective of this study was to identify the proportion of clinicians using USG to insert PIVCs in the ED following attendance at a hospital-based USG PIVC training program. Secondary objectives were to assess the effect of implementing a USG PIVC training course on USG PIVC uptake in the ED (proportion of PIVCs placed under ultrasound-guidance in the ED), clinician confidence and patient outcomes (rates of successful PIVC insertions, number of patients undergoing three or more insertion attempts). We also sought to describe potential barriers to PIVC USG insertion uptake in a large, academic teaching ED in Australia.

Methods

Design

A prospective observational study was conducted over 18 months from January 2017–2018 to evaluate the implementation of a USG PIVC training for ED clinicians. Historical data on department-wide practice was obtained prior to implementation of the program, in the same prospective observational manner used after the program.

Setting and sample

The study was conducted in a single site, academic ED with an annual census of approximately 110,000. The ED serves as a Level 1 trauma centre for adult and paediatric patients. With an admission rate of 28%, approximately 25–33% of patients arrive by ambulance. The ED is staffed by more than 150 full time equivalent (FTE) medical, and 200 FTE nursing staff. The ED has five portable ultrasound machines for use on the floor.

Intervention

The *USG PIVC training program* was delivered in a clinical simulation bay over two hours and consisted of three sections:

1 A 30-min didactic session, covering how to identify a vein on ultrasound, and common techniques for inserting PIVC under ultrasound guidance. Both short axis and long axis methods were taught. We educated staff of the evidence-based patient characteristics that make IV insertion more difficult, and encouraged early use of ultrasound for these patients. There was no formal difficulty assessment tool or escalation pathway used.
2 A 30-min session of practical vein mapping, where participants were oriented to the machines, identified landmarks, and assessed suitable veins with USS on their fellow trainees.
3 A 60-min practical session where ultrasound was used to place PIVCs in tissue models made from chicken breasts and fluid-filled balloons [19].

Competency assessment

On course completion, students were given a certificate of attendance. For a credentialing certificate, students were required to have three USG PIVC insertions witnessed and 'signed off' by an USG PIVC accredited staff member. On submission of this form, clinicians were provided with an USG PIVC credential certificate. Credentialing was not mandatory.

Current PIVC insertion practice

Current practice for PIVC insertion is landmark technique by medical, nursing, paramedical staff, and associated students. The unit does not have an assessment tool for the prospective identification of DIVA, or a formal escalation pathway for patients with DIVA. Ultrasound was typically used by a small number of generally senior staff with previous training, and initiated on an adhoc basis following multiple failed attempts.

Study procedures and measures

Data were obtained using paper-based data collection forms and entered and managed in Microsoft® Office Excel.

Phase 1. Pre implementation audit

During January 2017, a dedicated clinical research nurse (CRN) observed PIVC insertion practices in the ED for 40×4-h sessions, across the three shifts (morning, afternoon, and night). The CRN gained informed consent from admitted and arriving patients to the ED. Using a standardised data collection form, she collected information on predictors of difficult cannulation and PIVC insertion practices and outcomes (number of insertion attempts, successful cannulation, use of technology such as ultrasound). No changes were made to PIVC insertion practices during the pre-implementation observation period. Inserting clinicians were aware of the study, but instructed to practice as usual.

Phase 2. Implementation of the ultrasound-guided (USG) PIVC training course

All doctors and nurses who currently inserted PIVCs in the ED were invited to attend a free non-compulsory session on USG cannulation via email. The USG PIVC training program was delivered by up to six ED consultants and registrars with formal qualifications (certificates in clinician performed ultrasound [CCPU]) in point of care ultrasound/vascular access. Five training days were offered

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over 2017, with four sessions per training day (total of 20 training sessions offered). The USG PIVC training program was delivered in a standardised manner, with staff attending a single training session in person. Ultrasound machine models used in the training included Fujifilm, Sonosite, Philips Healthcare, GE Healthcare and Mindray ultrasound systems distributed by Life Healthcare. A video recording of the training sessions is available at (https://www.youtube.com/watch?v=JPT86q4zsKs).

Training session participants were informed of the study and invited to participate at commencement of the training session. Informed consent was obtained and a pre-training questionnaire administered. The questionnaire (purpose-built for the study) consisted of nine self-report questions assessing confidence with PIVC insertion (landmark technique) and confidence with PIVC insertion using USG. User confidence was measured on a 5-point Likert scale with 1 indicating low confidence and 5 indicating high confidence.

Approximately one month after training, an identical post-training questionnaire was emailed to all participants, to assess self-reported USG PIVC insertion confidence and usage of ultrasound-guided cannulation in the ED. Two follow-up emails were sent in the event of no reply.

Phase 3. Post implementation audit

In January 2018, one year after the USG PIVC training course was implemented, a CRN observed PIVC insertion practices in the ED, using previously described methods. This involved 27 × 4-h observations sessions, across the three shifts (morning, afternoon, and night).

Data analysis

Data was analysed in SPSS v24.0. Simple proportions were calculated for categorical measures, and compared between baseline and follow-up, or pre-workshop period and post-workshop period, as applicable. Chi-square tests were used to compare categorical variables; a p-value <=0.05 was considered statistically significant. The proportion of workshop respondents reporting using ultrasound post workshop was presented as a simple binomial proportion, with a 95% confidence interval (CI) calculated using the Wilson score. A change in confidence before and after workshops was assessed using the non-parametric Mann Whitney *U* test.

Research ethics statement

This paper reports the findings of a research study that adhered to the National Statement on the Conduct of Human Research by the Australian National Health and Medical Research Council and has been approved by the Gold Coast University Hospital Human Research Ethics Committee Approval HREC/16/QGC/245.

Results

Participant characteristics

Over 12 months, 195 clinicians attended the USG PIVC course, 149 (76%) were doctors, 32 (17%) nurses and 14 (7%) students or educators. Pre-training questionnaires revealed the majority of attendees (n = 146, 74% score of 4 or more) were confident with PIVC insertion using the landmark technique (Table 1). Two-thirds of participants (n = 131, 70%) indicated they had never used ultrasound before for peripheral cannulation, 25 (13%) used ultrasound annually, and 20 (11%) reported using it monthly. Follow-up post-training questionnaires were returned by 113 (58%) participants

Table 1
Participant characteristics.

Variable	n (%)
Role	
Doctor	149 (76)
Educator	6 (3)
Nurse	32 (17)
Student	8 (4)
Number of PIVCs placed in last 14 days	
Rare (<9 placed)	88 (45)
Moderate (10–29)	92 (47)
Frequent (30+)	14 (7)
Not answered	1 (1)
Number of PIVCs placed successfully on first attempt in last 14 days	
<=50%	13 (7)
51–89%	94 (48)
>=90%	71 (36)
Not applicable	17 (9)
Number of peripheral cannulation attempts escalated in last 14 days	
None	74 (38)
One	68 (35)
Two	19 (10)
3+	15 (7)
Not applicable/ did not answer	19 (10)
Confidence with peripheral cannulation	
Minimal	2 (1)
2	7 (4)
3	39 (20)
4	105 (53)
Very confident	41 (21)
Not applicable/did not answer	1 (1)
Ultrasound use for peripheral cannulation in last 14 days	
None	154 (78)
One	17 (9)
Two	3 (2)
3+	4 (2)
Not applicable/did not answer	17 (9)
Ultrasound use for peripheral cannulation in general	
Never	131 (66)
Weekly	11 (6)
Monthly	20 (10)
Annually	25 (14)
Not applicable/ did not answer	8 (4)
Confidence with ultrasound	
Minimal	114 (58)
2	30 (15)
3	28 (14)
4	6 (3)
Very confident	3 (2)
Not applicable/ did not answer	14 (8)
Prior education on ultrasound	
No	122 (62)
Yes	68 (35)
Not answered	5 (3)
Prior course on ultrasound	
No	158 (80)
Yes	32 (17)
Not answered	5 (3)

PIVC: Peripheral intravenous cannulas.

User confidence and application

Following course attendance, participant's perceived confidence to insert PIVCs using USG increased significantly from a median of 1 (interquartile range [IQR] 1–2) to 3 (IQR 3–4; p < .001)) (Fig. 1), with 43 (38%) respondents, indicating their confidence in USG cannulation was 4 or higher. Post training, 49 (43.3% (95% confidence interval [CI]: 34.5–52.6%)) respondents reported performing USG cannulation. The most common barriers reported to using ultrasound more frequently were: 'limited access to machine' and 'a feeling that it wasn't needed'.

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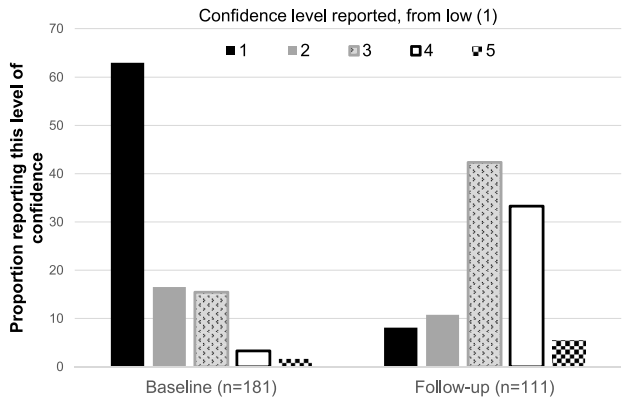

Fig. 1. Self-reported confidence with USG cannulation pre and post PIVC USG workshops.

Patient outcomes and PIVC insertion practices

A total of 567 patients were observed in the pre implementation period and 517 patients in the post implementation period. No clinically significant differences (e.g. triage category, sex or age distribution) were evident across the groups. Prior to course implementation, insertion attempts in the ED ranged from 1 to 10 per patient, with 51 (9%) patients requiring three or more attempts before success, and two failed cannulations (Table 2). Post course implementation, the number of cannulation attempts ranged from 1 to 9, with 49 patients (9.5%) requiring three or more attempts, and five failures (p = not significant). Ultrasound was used on 4 (0.7%) and 31 (6.0%) cannulations respectively ($p < .001$). Of the 31 USS-guided cannulations, 35 people attempted the cannulation with USS. Of these 35 people, 4 were nurses, 13 junior doctors (intern, resident), and 18 were senior doctors (registrar, consultant). Workshops did include education on patient selection, which may account for an (not statistically significant) improvement in using ultrasound earlier (i.e. use of ultrasound on the third or higher attempt: 75% before vs 58% after training), ($p = 0.58$) (data not shown). Overall, first attempt success with USG cannulation was 62.9%.

User satisfaction with course

Overall, 106 (94%) participants reported finding the workshop 'very useful'.

Discussion

Overall, the training workshops increased confidence and use of ultrasound-guided cannulation amoung participants. Departmentally, there was no change in the number of patients requiring 3 or more attempts, nor overall success, despite the use of ultrasound increasing.

We found implementation of an USG PIVC training course was feasible and led to the increased use of ultrasound in a large tertiary ED. Implementation of this course led to increased user confidence with ultrasound, however, less than half of respondents reported using this practice post workshop, indicating there is an ongoing need for USG skills training to enhance procedural retention. Ongoing competency and skill retention is a documented challenge of implementing USG courses. While the availability of point of care ultrasound has been shown to improve first attempt insertion rates, reduce the need for multiple attempts and increase user satisfaction, there is a learning curve associated with USG PIVC confidence and competence [12,18,20,21]. Recent surveys of practice have demonstrated clinicians want access to USG training courses to develop cannulation skills, specifically in the context of patients with DIVA [22]. However, ongoing skill development and support is crucial for embedding this skill in practice. Although we observed that the use of USG PIVC insertion remained infrequent post-workshops (6%), this represented more than an eight-fold increase in the use of ultrasound in the measurement period before the workshops. This likely indicates that a small group of people confident in USG cannulation increased their use, but the number of staff using it remained small. The training, credentialing and quality assurance aspects of USG PIVC are recognised challenges in the literature [23] which warrant further research as the scope of USG PIVC insertion expands in ED.

Overall, our first attempt success with USG cannulation was ~63%, which correlates well with the literature, which reports 53–73% [2,14]. However, training in USG cannulation did not change the proportion of patients requiring 3 or more attempts, nor overall success. Overall, this suggests the training sessions were useful to learn the skill itself, but further emphasis needs to be placed on identifying patients who possess predictors of difficult cannulation, and using ultrasound early in this group, rather than missing a few times before turning to ultrasound. Workshops did include education on patient selection, which may account for improvement in using ultrasound earlier (i.e. use of ultrasound on the third or higher attempt: 75% before vs 58% after training). The prospective identification and escalation of patients identified as having DIVA is likely to include the use of USG and lead to improved patients' outcome [22]. Several studies have sought to develop and validate DIVA clinical resources [10,24], however, further work is needed to assess their utility and ease of use in the ED.

The workshops were largely attended by medical staff (76%), despite invitation by email and poster displays being distributed

Table 2
Univariate analysis of training outcomes.

	Before workshops (n = 567)		After workshops (n = 517)		
	n	%	n	%	p-value
Cannulation attempts					
1	443	78.1	388	75.0	0.42
2	73	12.9	80	15.5	
3+	51	9.0	49	9.5	
Maximum:	10 attempts		9 attempts		
Average:	1.38		1.40		
Was cannulation successful?					
Yes	565	99.6	512	99.0	0.27
No	2	0.4	5	1.0	
Use of ultrasound to guide cannulation					
USS used	4	0.7	31	6.0	<0.00
USS not used	563	99.3	486	94.0	

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to both medical and nursing staff. The majority of the cannulas inserted in our ED are done so by nursing staff, and thus the majority of those inserted in the pre- and post-workshop observation periods were done by nursing staff. In our department, nursing staff have allocated time dedicated to training or up-skilling, and if these days did not fall on a day where our workshop was offered, nurses were unavailable to attend. It is also likely that nurses felt less welcome to the workshops, as they were run by medical staff. Inclusion of nursing team members in the training workshops, and co-ordinating training time with workshops, are likely to increase their participation.

Few studies have investigated the barriers to implementing USG PIVC insertion in the ED. Interviews conducted with Dutch ED physicians (n = 8) regarding application of point of care ultrasound for diagnostic imaging [25] found access to ultrasound machines was a significant barrier to its uptake. USG machine access has been reported in the literature as on ongoing challenge for not using ultrasound to insert PIVCs [22], this is a significant consideration for healthcare organisations and policy makers looking to embed USG PIVC insertion into routine clinical practice. There may be a greater need for more ultrasound machines, especially in areas of high cannulation i.e. triage, resus. Our study found barriers include feeling that it was not required. This, again, may reflect a need for further education regarding characteristics that predict difficulty in inserting PIVCs and the need for a formal vein assessment tool and escalation protocol.

There may also be a role for educating and empowering our patients to encourage them to request ultrasound if they know they are difficult to cannulate. Locally, posters, wristbands and videos in waiting rooms are being developed for this reason. More research will be needed after implementing these changes to monitor if cannulation practices improve.

Limitations

This study was an observational before and after study. Although data collection was done prospectively in both periods, and both periods were staffed by a cohort of junior doctors with similar clinical experience, it could be that the department-wide changes were due to some other unreported variable, such as a general improvement in cannulation practice over time. Secondly, workshop follow-up was 58% of workshop participants. This follow-up rate is quite poor, and may have a large impact on self-reported results of workshop participants. Participants were contacted and reminded three times. This contact came from the medical professional who ran the workshop, who was often a supervisor of workshop attendees, so people with negative feedback may have avoided completing the post-workshop questionnaire. The requirement for anonymity meant that we could not target individuals for follow-up, and nor could we link post-surveys to pre-surveys. It may be, therefore, that the proportion of participants using ultrasound in the follow-up period is lower than reported, as clinicians not using ultrasound might be less likely to respond. It may also be that this non-respondent group perhaps did not find the workshops useful and were reluctant to respond. Our results are generalisable to ED medical staff given this group reflects the majority trained. Finally, the faculty of the training workshops was all medical, and these workshops were largely attended by doctors, despite advertising emails/posters available to all staff. The majority of PIVCs are inserted by nursing staff in our ED, yet only 16% of the attendees at the training workshops were nursing. Perhaps inclusion of a nurse(s) in future training sessions would increase nursing attendance.

Conclusions

PIVCs are the most commonly inserted intra-vascular device in the ED. Considered a simple procedure, some patients are recognised as difficult to cannulate, leading to delays in investigations and treatment, prolonging ED stay and impairing patient flow. In all patients needing IV treatment, we should consider characteristics for difficult cannulation. If present, USG cannulation should be utilised on the first attempt. A formal vein assessment tool and escalation pathway for difficult patients would likely be useful, and more research is required to assess its practical use in the ED. Training staff in the use of USG cannulation is well received and increases short-term confidence, however we need to ensure this training is coupled with education in patient selection and advice to use ultrasound early, rather than having several unsuccessful attempts before it is considered. A follow-up session to allow repeat education and practice by participants may increase uptake, and further research is required to assess its effects. These training workshops should include nursing staff as faculty to encourage nursing attendance. Increased availability of ultrasound machines may also increase uptake.

Author contributions

AAJ contributed to the study concept and design, acquisition of funding, analysis and interpretation of the data, drafting of the manuscript, and critical revision of the manuscript. SW contributed to the study concept and design, acquisition of funding, and critical revision of the manuscript for important intellectual content, LJ and AG contributed to acquisition of the data, analysis and interpretation of the data; AS contributed to the study concept and design, acquisition of funding, analysis and interpretation of the data, statistical expertise, drafting of the manuscript, and critical revision of the manuscript. JS and CR reviewed and critically revised the final manuscript for submission.

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Conflict of interest disclosures

AAJ and SW are employed casually as faculty members of the Australian Institute of Ultrasound.

JS reports investigator-initiated research grants provided to Griffith University from vascular access product manufacturers Becton Dickinson, unrelated to this project.

CR reports investigator-initiated research grants and speaker fees provided to Griffith University from vascular access product manufacturers (3M, Angiodynamics; Baxter; BBraun; BD-Bard; Medtronic; ResQDevices; Smiths Medical), unrelated to this project.

AS, LJ and AG report no conflict of interest.

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