



Original Contribution

ED technicians can successfully place ultrasound-guided intravenous catheters in patients with poor vascular access^{☆,☆☆}

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Abstract

Objective: The objective of the study was to assess the success rate of emergency department (ED) technicians in placing ultrasound (US)-guided peripheral intravenous (IV) catheters.

Methods: In this prospective, observational trial, 19 ED technicians were taught to use US guidance to obtain IV access. Training sessions consisted of didactic instruction and hands-on practice. The ED technicians were then prospectively followed. The US guidance for IV access was limited to patients with difficult access. The primary outcome was successful peripheral IV placement.

Results: A total of 219 attempts were recorded, with a success rate of 78.5% (172/219). There was a significant correlation between operator experience and success rate. Complications were reported in 4.1% of patients and included 5 arterial punctures and 1 case of a transient paresthesia.

Conclusions: Emergency department technicians can be taught to successfully place US-guided IVs in patients with difficult venous access. Teaching this skill to ED technicians increases the pool of providers available in the ED to obtain access in this patient population.

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1. Introduction

Establishing peripheral intravenous (PIV) access in patients with difficult vascular access due to obesity, history of IV drug use, chronic illness, and vascular pathology is a common problem faced in the emergency department (ED) [1-5]. Traditionally, patients who have failed routine

methods of IV access have required central venous catheters, peripherally inserted central catheters, external jugular IVs, or, more recently, ultrasound (US)-guided vascular access [3-6]. Such access is almost always obtained by physicians, distracting them from other tasks of patient management and impairing ED flow [1,5-8].

In recent years, US has been used successfully in guiding the placement of central venous catheters. This has resulted in a significant improvement in success rate and decreased complication rate [3-5]. Considering the potential benefits of this application and seeking to further minimize the risks associated with central lines, emergency physicians began using US for the placement of PIV catheters in patients in whom vascular access was challenging [1,5,9,10,11].

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Previous studies have demonstrated that physicians and nurses can learn to place US-guided peripheral lines to obtain access in patients who fail routine access attempts [1,5-11]. Providers other than nurses and physicians, such as technicians, nursing assistants, and prehospital personnel, are routinely trained in the skill of IV placement. However, training in US-guided PIV access has typically been restricted to nurses and physicians [7,8,10-12]. If ED technicians are able to successfully place US-guided IVs in patients who have failed traditional access, interruptions to physicians could be greatly decreased. Furthermore, the burden of time spent obtaining IV access in patients with poor peripheral access would shift from physicians to ED technicians [12]. Higher success rates of PIV cannulation and reduced need for central venous access may result in increases in patient safety and satisfaction [10-12]. A recent study by Bauman et al [12] evaluated teaching this skill to ED technicians.

The goal of this study was to determine whether ED technicians could learn to successfully and consistently place US-guided PIVs after a brief training intervention. We sought to assess the learning curve and the success rate of the technicians compared with physicians and nurses in previous studies.

2. Methods

2.1. Study design

This study was a prospective observational study conducted at the ED of the George Washington University Hospital, with approximately 68 000 ED patient visits per year and a residency training program in emergency medicine. The Department of Emergency Medicine, with the support of the George Washington Hospital nursing administration, adopted the protocol of US-guided IV access as performed by ED technicians. Data were collected on consecutive patients who presented between January 2008 and September 2008. This study was approved by the George Washington University Medical Center Institutional Review Board.

2.2. Study setting and population

The study subjects were emergency medical technicians already employed by the hospital. Their responsibilities in the hospital include but are not limited to the following: IV insertion and phlebotomy, urinary catheter insertion and care, wound preparation, application of splints and orthopedic devices, point of care testing, obtaining vital signs, and performing electrocardiograms. Study participation was voluntary, and written informed consent was obtained from all ED technicians participating in the study.

Patients became eligible for the study if they were at least 18 years of age, required an IV line, and had undergone 2 failed PIV attempts or were known to have difficult vascular access from previous visits. Patients were excluded from the trial if they were unstable or otherwise required central venous catheter or another form of emergency IV access.

2.3. Study protocol

The ED technicians were offered a 2-hour training session offered multiple times from January through June 2008 in groups of 3 to 5 technicians per 1 instructor at a time. The first hour consisted of a didactic presentation discussing principles of ultrasonography, care and disinfection of the US machine, how to use the US properly to identify and cannulate veins, and the upper extremity venous anatomy. The second hour consisted of hands-on training where the technicians were encouraged to trace veins in live models' arms and practice IV insertion on gel phantoms (Blue Phantom, Kirkland, WA). The ED technicians were instructed to use dynamic single operator technique, in which the person placing the IV holds the probe in his or her nondominant hand and concurrently places the IV with his or her dominant hand visualizing and guiding the needle entrance in real time. Both transverse (short axis) and longitudinal (long axis) methods were demonstrated; but ED technicians were encouraged to start with the transverse method, as this method has been shown to have a higher success rate among novice operators [13-17].

During the training sessions, the upper extremity venous anatomy was reviewed with the ED technicians. Participants were encouraged to first look at the antecubital veins and forearm vasculature before looking at the brachial and basilic veins. Training stressed that larger, more superficial veins were likely to be more easily cannulated. The ED technicians were taught to measure depth via US to ensure that the catheters used were of adequate length [14,18,19].

A 10-question quiz was given at the end of each training session, stressing the key points of both obtaining US-guided access and caring for the US machine. The quiz was reviewed with the technicians.

Materials for US-guided IV access were made available in the ED. Two Sonosite M-Turbo US machines (Sonosite, Bothell, WA) with 13-6 MHz linear probes were readily available in the ED. All IV insertion equipment was also available, including 1.88-in, 20-gauge angiocatheters.

After completion of the training session, the ED technicians were allowed to start using the US for patients with difficult access. The ED technicians were instructed not to use the US unless someone had attempted traditional IV access at least twice or the patient was well known to the ED staff as having difficult access that had required alternative methods in the past.

Each US machine in the ED was equipped with a folder containing blank surveys and a folder for completed

surveys. After attempting IV access via US guidance, the ED technicians filled out a survey and noted the attempt in the patient's electronic medical record. The survey included the number of traditional attempts before use of US guidance, the number of US-guided attempts before successful cannulation, reason for difficult vascular access, the number of previous US-guided IVs placed by ED technician, the years of experience as an ED technician, the duration of experience with putting in IVs, the applied vein (listed with a diagram), and complications and final route of IV access in patients with unsuccessful US-guided IV access.

2.4 Data analysis

Surveys were collected from the folders by study investigators and entered into an Excel database. The primary outcome was success rate of US-guided venous cannulation. Secondary outcomes included complication rate and the rate of success based on previous ED technician experience with both standard IV insertion and US-guided IV insertion. A *successful IV attempt* was defined as blood return or ability to infuse IV fluid without infiltration.

In an effort to further characterize these IVs, data were also collected regarding site of eventual cannulation and the reasons for patients' poor peripheral vascular access. Continuous variables were expressed as mean \pm standard deviation and compared by use of paired Student *t* test. Categorical data were summarized using proportions and 95% confidence intervals. Spearman correlation analysis was used to compare continuous and ordinal data. Ordinal data, such as years of experience placing IVs or previous US-guided IVs placed, were compared using the exact version of the Cochran-Armitage test for trend in SAS (SAS Institute, Inc, Cary, NC). A *P* value $<$.05 was considered to be statistically significant. All data was analyzed using the SAS statistical software version 9.

3. Results

In this study, 19 ED technicians completed a total of 219 surveys. Of the 219 surveys, 172 reported successful placement of a US-guided IV, for a success rate of 78.5%. For the patients with successful IV placement, a mean of 1.35 ± 0.56 (95% confidence interval, 1.26-1.43) attempts was required before IV catheterization.

Success rate varied by the years of prior experience the ED technicians had with both US-guided IVs and previous routine (non-US) IV access (Figs. 1 and 2). The rate of success was directly proportional to the number of previous US-guided IVs placed by the ED technician. Emergency department technicians with more than 10 previous successful US-guided IVs had a success rate of 86.8%, compared with only 45.8% in ED technicians with 0 to 3 prior successfully placed US-guided IVs ($P < .0001$). Similarly, those with greater than 2 years' experience putting in non-US-guided IVs had an 87% success rate, compared with 44% when attempted by ED technicians with less than 2 years' experience ($P = .004$). Using the exact version of the Cochran-Armitage test for trend in SAS, there is a highly significant relationship between experience and success for both categories of experience ($P < .001$).

Sixty-one percent of successfully placed IVs were placed in antecubital veins or distally; and 15.1% and 20.9% were placed in deep brachial or basilic veins, respectively. A total of 5 arterial punctures were noted (2.3%) as well as 1 transient paresthesia and 3 other undefined complications, for a complication rate of 4.1%. The ED technicians noted reasons why the patient had poor peripheral access and were encouraged to include all answers that applied (Table 1).

4. Discussion

Obtaining IV access in patients for whom access is difficult is a common challenge in the ED and adversely

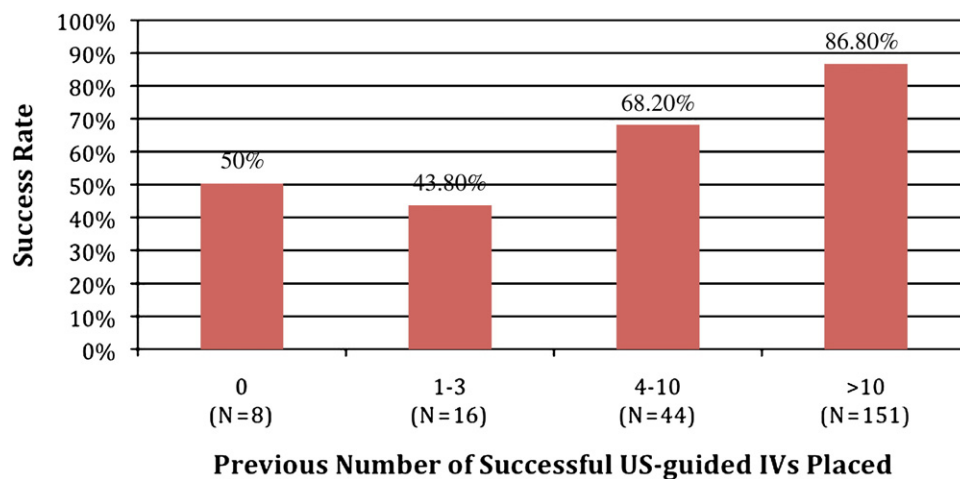


Fig. 1 Success rate based on prior success with US-guided IVs.

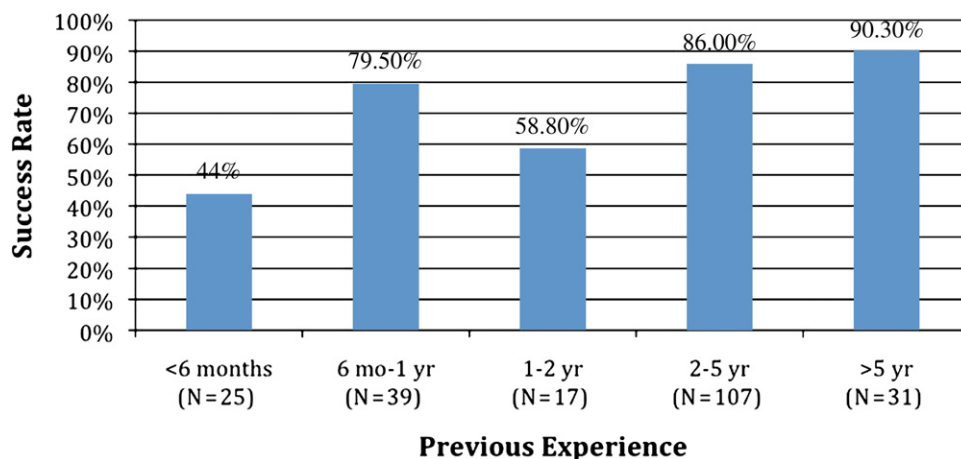


Fig. 2 Success rate by prior experience with routine vascular access.

affects physician efficiency when alternate time-consuming procedures are needed [4,5,10,13,19]. In search of alternative providers, we decided to incorporate US-guided IV access in the practice of ED technicians who, in our ED, are currently the first providers to attempt IV access in ED patients. Integrating this ability into the skill set of ED technicians will help rapidly and safely obtain IV access for those patients in whom access otherwise would be difficult and time consuming.

The results of the study suggest that ED technicians can be trained in the skill of placing US-guided PIVs. Although their success rate of 78.5% was somewhat lower than reported for physicians and ED nurses in previous studies, we believe this is still a very acceptable success rate, particularly in light of the low complication rate, the relatively small time investment on the part of the coordinating physicians, and the invasiveness of alternatives to this for IV access, such as central lines [9,10,20,22,23]. Although we did not study directly whether our intervention decreased interruptions to the residents and attending physicians in our clinical unit, all 219 patient encounters studied would have resulted in a physician being notified of failed access before the implementation of the current protocol of US-guided IV

placement by ED technicians. We believe that this intervention decreased disruption of physician duties.

The differences in success rates between prior studies and our study could be explained by several confounding variables. In our study, the ED technicians were taught only the 1-operator method, whereas other studies used the 2-operator method [1,3]. Whereas some of the studies noted in Table 2 were teaching this skill for the first time [3], as in this study, others note that some of their operators had prior experience [1]. We clearly demonstrated that increased experience significantly increases success rates.

Our study was conducted immediately after training; and therefore, a well-documented learning curve was noted. It was clear that success rate improves with time and practice. Interestingly, 2 independent factors were associated with increasing success rate. First, the number of prior US-guided IV attempts was important, with the learning curve being such that after placing 10 US-guided lines, the success rate rose to 87%. Second, the amount of experience the ED technicians had placing (non-US-guided) IVs was important as well; ED technicians with more than 5 years' experience in placing IVs had a 90.3% success rate. This is logical, as there are 2 separate skills involved in placement of the US-guided IV: using the US to visually guide the needle/catheter unit through tissue into the vessel and the successful cannulation of the vessel by advancing the cannula off the needle after "flash" is obtained.

It is notable that most successful cannulation attempts used veins at or distal to the antecubital fossa, rather than the deep arm veins such as the deep brachial and basilic. To date, there has been no research on whether repeated access of the deep veins causes permanent damage, scarring, or stenosis; but because these veins are often vital to fistulas created for hemodialysis, it is reasonable to avoid these veins in any patient with end-stage renal disease, chronic renal insufficiency, or severe underlying disease, such as hypertension or diabetes, that may lead to a need for dialysis [6].

Finally, although several studies have documented both high success rates and ease of teaching, few have investigated

Table 1 Reported reasons for poor PIV access

Reason for poor access	n	% ^a
Scarred veins from prior access	125	57
Chronic illness requiring frequent blood draws	108	49.3
Dehydration	48	21.9
Obesity	34	15.5
IVDA	33	15.1
Renal failure	12	5.5
Sickle cell	9	4.1
Edema	5	2.3
Other/unknown	62	28.4

IVDA, intravenous drug abuse.

^a Values do not add up to 100% because survey asked ED technicians to indicate all that apply.

Table 2 Comparison of success rates of similar studies

Study	Total n	Success rate	Attempts per success	IV access provider	Arterial puncture
Keyes et al (1999)	101	91%	Not reported	Physicians	2.0%
Costantino et al (2003)	51	92%	Not reported	Physicians	2.0%
Costantino (2005)	39	97%	1.7	Physicians	0%
Brannam (2006)	321	87.2%	Not reported	Nurses	1.25%
Our study (2009)	219	78.5%	1.3	ED technicians	2.3%

the natural history of these IVs. Keyes et al [21] noted that 8% of deep brachial IV lines infiltrated within an hour; and other studies have suggested ways of making these lines last longer, including using the Seldinger technique to place a 15-cm catheter after access is obtained using a standard-sized catheter [3,7]. Further research is needed to examine patients' experience with these IVs, their durability, and any possible complications that are not obvious at the time of placement.

4.1. Limitations

Our study has several important limitations. As there were no independent research assistants collecting data on US-guided IV attempts, it is possible that the ED technicians did not record every attempt they made at US-guided IV access. It is also possible that ED technicians were less likely to fill out data sheets when they were not successful. This would mean that the success rate noted is artificially elevated. However, it is clear that the ED technicians did note many failed attempts, which we believe adds credibility to their success rate.

A second notable limitation is that individual ED technicians who are proficient at US-guided lines are more likely to do more of them, positively affecting the success rate, whereas technicians who are not good at these lines will stop attempting them, also positively affecting success rate.

Another limitation of this study is that, although we are presuming that when ED technicians are proficient at this skill, interruptions to physicians will decline, we did not directly study this. We also did not collect data on the durability of these IVs, the rates and characteristics of longer-term complications such as infection and loss of function of the IV, and patient perceptions of these US-guided lines placed by ED technicians. Further study is needed to try to address these questions.

4.2. Conclusions

This study demonstrated that ED technicians can successfully and safely perform US-guided PIVs in patients with difficult IV access after a brief training session. Teaching this skill to ED technicians increases the number of providers in the ED who can obtain access on patients who previously needed a physician to obtain IV access. Further

investigation is needed to determine whether giving ED technicians this skill set significantly affects physician interruptions, ED patient flow, and need for invasive procedures like central venous access.

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