Ultrasonography-Guided Peripheral Intravenous Access Versus Traditional Approaches in Patients With Difficult Intravenous Access

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Study objective: We assess the success rate of emergency physicians in placing peripheral intravenous catheters in difficult-access patients who were unsuccessfully cannulated by emergency nurses. A technique using real-time ultrasonographic guidance by 2 physicians was compared with traditional approaches using palpation and landmark guidance.

Methods: This was a prospective, systematically allocated study of all patients requiring intravenous access who presented to 2 university hospitals between October 2003 and March 2004. Inclusion criterion was the inability of any available nurse to obtain intravenous access after at least 3 attempts on a subgroup of patients who had a history of difficult intravenous access because of obesity, history of intravenous drug abuse, or chronic medical problems. Exclusion criterion was the need for central venous access. Patients presenting on odd days were allocated to the ultrasonographic-guided group, and those presenting on even days were allocated to the traditional-approach group. Endpoints were successful cannulation, number of sticks, time, and patient satisfaction.

Results: Sixty patients were enrolled, 39 on odd days and 21 on even days. Success rate was greater for the ultrasonographic group (97%) versus control (33%), difference in proportions of 64% (95% confidence interval [CI] 39% to 71%). The ultrasonographic group required less overall time (13 minutes versus 30 minutes, for a difference of 17 [95% CI 0.8 to 25.6]), less time to successful cannulation from first percutaneous puncture (4 minutes versus 15 minutes, for a difference of 11 [95% CI 8.2 to 19.4]), and fewer percutaneous punctures (1.7 versus 3.7, for a difference of 2.0 [95% CI 1.27 to 2.82]) and had greater patient satisfaction (8.7 versus 5.7, for a difference of 3.0 [95% CI 1.82 to 4.29]) than the traditional landmark approach.

Conclusion: Ultrasonographic-guided peripheral intravenous access is more successful than traditional ''blind'' techniques, requires less time, decreases the number of percutaneous punctures, and improves patient satisfaction in the subgroup of patients who have difficult intravenous access. [Ann Emerg Med. 2005;46:456-461.]

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INTRODUCTION

Background

Peripheral intravenous access is commonly performed in the emergency department (ED) to collect blood specimens and to provide a route for intravenous medication and fluid administration. Although this procedure is usually performed by nurses, in cases of difficult access emergency physicians are often called on to perform this task. The landmark technique for peripheral intravenous access has a success rate of 90% for ED patients.[1] However, that still leaves many patients who require intravenous access but are difficult to cannulate, often because of obesity, a chronic medical condition, or a history of intravenous drug abuse. Patients who fail peripheral intravenous access will often have an external jugular intravenous line placed or undergo central venous access.

Emergency ultrasonography may provide an opportunity to increase the success rate of peripheral intravenous access. Ultrasonographic guidance for central venous access has been well studied throughout the past 2 decades, with several studies showing an increased success rate or decreased complications compared to the traditional landmark approach.[2-6] However, we know of only 1 observational study

Editor's Capsule Summary

What is already known on this topic

Ultrasonography is helpful for central line placement. Its utility in the placement of peripheral lines in patients whose peripheral veins are difficult to access by standard techniques is unknown.

What question this study addressed

This study compared randomized ultrasonography-guided peripheral intravenous insertion with traditional peripheral intravenous insertion in a subset of emergency department patients with difficult intravenous access.

What this study adds to our knowledge

The use of ultrasonography to guide peripheral intravenous insertion markedly decreased the time needed to achieve intravenous access, decreased the number of attempts, and increased patient satisfaction.

How this might change clinical practice

This study suggests that practitioners who gain expertise in this skill will be able to obtain peripheral intravenous access in patients who would otherwise be subjected to multiple attempts, require central line placement, or both.

that has examined ultrasonographic guidance of peripheral intravenous access.[7]

Importance

Ultrasonographic guidance may improve the rate of successful peripheral intravenous access in patients who have been historically difficult to access, leading to less time spent obtaining intravenous access and greater patient satisfaction. Ultrasonographic guidance may also decrease the number of central venous access attempts and lead to fewer overall complications.

Goals of This Investigation

We present a study comparing ultrasonographic-guided peripheral intravenous access versus intravenous access without ultrasonographic guidance in a subset of patients with difficult-to-obtain intravenous access, experienced emergency nurses having failed at least 3 intravenous access attempts. The primary endpoint was successful cannulation. Secondary endpoints included number of percutaneous sticks required, time of procedure, overall patient satisfaction, and complications.

MATERIALS AND METHODS

Study Design

This was a prospective, nonblinded, systematically allocated study comparing ultrasonography-guided peripheral intravenous access with a traditional approach. Patients were systematically allocated to the ultrasonography-guided or the landmark and palpation (control) group based on their presentation to the ED on an odd (ultrasonography) or even (control) day. This study was approved by the institutional review board of the respective institutions, and patients gave informed consent before entering the study.

Setting

The study was performed at 2 urban, tertiary-care, university hospital EDs with a combined annual ED census of about 60,000 visits. Data were collected on consecutive patients who presented between October 2003 and March 2004.

Selection of Participants

Pregnant patients and children were excluded, as were those who were unable to give consent. Inclusion criterion was inability of any available nurse to obtain intravenous access after at least 3 attempts on a subgroup of patients who had a history of difficult intravenous access because of obesity, history of intravenous drug abuse, or chronic medical problems. Exclusion criterion was the need for central intravenous access as defined by the treating physician. Patients randomized to the traditional approach, who failed peripheral intravenous access by physicians after 3 further attempts, and who were to have a central venous access placed could opt into a "rescue" pathway in which they would be allowed to have ultrasonography-guided peripheral venous access.

Ultrasonographic guidance was performed in real time using either a Seimens Versapro (Erlangen, Germany) with a 7.5-MHz transducer or a Sonosite 180plus (Bothell, WA) with an 8-MHz linear transducer. One operator held the probe proximal to the insertion site in a transverse plane to the vessel to be cannulated (Figure 1). Vessels were searched for by ultrasonography in their suspected anatomic position in the arm. Once found, vessels were lined up in the middle of the probe. Veins were identified by their ease of collapse with mild probe pressure. A second physician operator then ascertained the location and depth of the vessel by viewing the ultrasonographic screen. After usual sterile preparation, the second operator advanced an 18-gauge 1.25-inch angiocatheter into the vessel. Ultrasonographic appearance of an angiocatheter in a brachial vein is shown in Figure 2. Successful cannulation was confirmed by aspirating 5 mL of blood.

Veins were identified using palpation and visual inspection. The external jugular vein was included in this group, if available. There was no restriction on the size of the angiocatheter used.

The study was performed by emergency medicine residents and attending physicians who were familiar with emergency ultrasonography from residency training and attended a 1-hour didactic session on ultrasonographic-guided peripheral and central venous access. Residency training included a 3-week rotation in the ED, doing emergency ultrasonography, with a minimum of 15 hours of didactic lecture and 100 emergency ultrasonographic scans performed.

Figure 1. The ''2-person'' method of peripheral intravenous access using ultrasonographic guidance.

Table. Patient demographics and variables across groups.

Patient Data	Ultrasonography (±SD) (N=39)	Control (N=21)
IVDA, No. (%)	11 (28)	5 (24)
Chronic medical condition, No. (%)	19 (49)	12 (57)
Obesity, No. (%)	9 (23)	4 (19)
Success, No. (%)	38 (97)	7 (33)
Total time, minutes, median	13±25.4	30±21.3
Time of attempt, minutes, median	4±5.6	15±11.8
No. of sticks	1.7±0.7	3.7±2
Patient satisfaction	8.7±1.6	5.7±3.2

IVDA, Intravenous drug abuse.

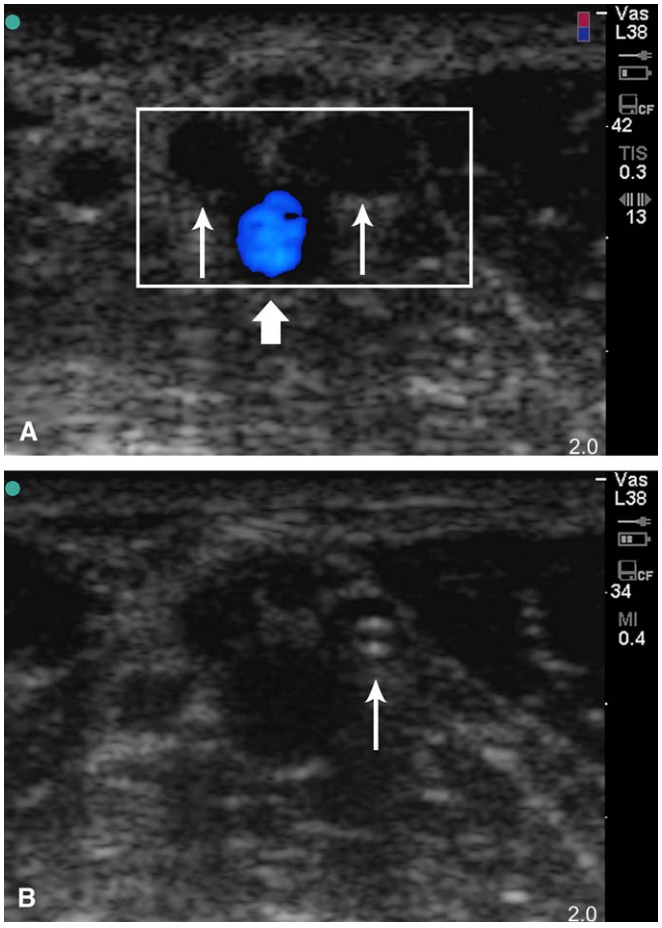

Figure 2. *A,* Brachial artery (thick arrow) with flow from color power Doppler (CPD) and 2 brachial veins (thin arrows). *B,* Intravenous catheter in one brachial vein with reverberation artifact (thin arrow). CPD is not necessary as veins can usually be distinguished from arteries by their easy compressibility.

Outcome Measures

The endpoints measured were (1) intravenous access success rate; (2) time from first percutaneous perforation to successful cannulation (self-reported); (3) time from request for physician-performed intravenous access to successful establishment of intravenous access (self-reported); (4) number of percutaneous perforations required; (5) patient satisfaction with intravenous access (a Likert scale from 0 to 10 was used to gauge patient satisfaction); and (6) complications from intravenous access, including brachial artery puncture, large artery puncture, pneumothorax, neck hematoma, or other significant complications, as decided by the treating physician.

Primary Data Analysis

Data are presented as median±SD. Nonparametric Mann-Whitney *U* analysis of variance was used to analyze significance of time data and number of cannulations.

Frequency data significance was determined by Fisher exact test.

RESULTS

Main Results

Results are summarized in the Table. Sixty patients were enrolled: 39 on odd days and 21 on even days. Success rate was greater for the ultrasonographic group (97%) versus the control group (33%), with a difference in proportions of 64% (95% confidence interval [CI] 39% to 71%). The median total time required from first percutaneous puncture until successful cannulation was also significantly less in the ultrasonographic group (4±5.6 minutes versus 15±11.8 minutes, for a difference of 11 minutes [95% CI 8.2 to 19.4 minutes]). The median total time from notification by a nurse until successful cannulation was less in the ultrasonographic group (13±25.4 minutes) than in the control (30±21.3 minutes, for a difference of 17 minutes [95% CI 0.8 to 25.6 minutes]). There were significantly fewer percutaneous punctures in the ultrasonographic group (1.7±0.7) than in the control group (3.7±2), for a difference of 2.0 (95% CI 1.27 to 2.82). Patient satisfaction was also significantly higher in the ultrasonographic group (8.7±1.6) versus the control group (5.7±3.2), for a difference of 3.0 (95% CI 1.82 to 4.29). There were no significant complications in either group. Two neck hematomas resulted from attempted external jugular vein cannulation and resolved spontaneously.

In the control group, there were 14 of 21 failures. Three patients went straight to central venous access, all of which were successful, with 1 complication. The 11 patients with failed attempts who entered the rescue pathway all had peripheral venous access successfully established by ultrasonographic guidance, with an average of 1.8±0.7 attempts. These were not included in the data for the ultrasonographic group.

In the ultrasonographic group, of the 38 successful placements, the breakdown of location was as follows: antecubital 16, brachial 15, forearm 3, cephalic 3, and basilic 1. The rate of successful intravenous cannulation was 18 of 39 (46%) after 1 attempt, 18 of 39 (92% total) after 2 attempts, and 2 of 39 (97% total) after 3 attempts. The location of successful intravenous placement in the control group was 4 in the external jugular vein and 3 in forearm and hand veins. For the control group, the success after 1 attempt was 5 of 21 (24%), after 2 attempts was 1 of 21 (29% total), and after 3 attempts was 1 of 21 (33% total).

Twenty physicians participated in the study. No physician enrolled more than 6 patients. If physicians were arbitrarily broken down into "more experienced" (N=4, 3 attending physicians and 1 resident) and "less experienced" (N=16, all residents) based on having placed more than 10 previous ultrasonography-guided peripheral intravenous catheters, 22 of 23 patients had peripheral intravenous catheters successfully placed by "less experienced" physicians. Sixteen of 16 patients were successfully cannulated by "more experienced" physicians. All physicians reported having successfully placed more than 10 external jugular intravenous catheters and 10 forearm intravenous catheters. In the control group, "more experienced" (with ultrasonography-guidance placement) physicians placed 4 of 8 peripheral intravenous catheters successfully using landmark and palpation. Three of 13 intravenous catheters were successfully placed by "less experienced" (with ultrasonography guidance) physicians. In the rescue pathway, 3 of 11 intravenous catheters were placed by "more experienced" and 8 of 11 by "less experienced" physicians; all placements were successful using ultrasonographic guidance.

LIMITATIONS

Despite our attempts at systematic allocation, there were almost twice as many patients enrolled in the ultrasonographic group as there were in the control group. The 3 extra odd days in the study period do not explain all of the difference. We strongly suspect selection bias occurred. We had no mechanism for checking whether eligible patients were always enrolled in the study, which may have biased the results toward a greater difference between ultrasonographic guidance and traditional approaches. Future studies should have a mechanism to ensure the enrollment of all eligible patients.

There was no follow-up of patients in the study. Thus, patients with delayed complications were not detected. Also, previous studies noted a tendency for the more deeply placed intravenous lines to become inoperable relatively soon after placement.[8] Although there were some anecdotal reports, it did not seem to be a major problem. Future studies could address this issue by using longer-term patient follow-up and using different catheter lengths.

The control group had 8 external jugular vein cannulations attempted (4 successfully) versus none in the ultrasonographic-guided group. We allowed the traditional-approach group to use the external jugular vein because that is what many emergency physicians do in the "real world" when confronted with difficult intravenous access instead of blindly attempting to place arm intravenous catheters. Although this method does introduce more bias, we think it is in favor of the control group and should not lead to a wider difference in success rate between the 2 groups.

DISCUSSION

Intravenous access is commonly required for patients presenting to the ED. All emergency physicians need to be familiar with techniques for obtaining intravenous access. Many emergency physicians are familiar with a subgroup of patients in which intravenous access can be very difficult, usually because of obesity, history of intravenous drug abuse, or some chronic medical condition that can distort the normal vascular anatomy, such as patients who have end-stage renal disease and are receiving hemodialysis. Many of these patients may eventually require central venous access to receive medication and have blood obtained for testing.

Ultrasonographic guidance for central venous access was first reported in 1984.[6] Since then, numerous studies have shown the benefits of using ultrasonographic guidance for central venous access.[2-5] With recent statements from the Agency for Healthcare Research and Quality recommending real-time ultrasonographic guidance for all central venous access, emergency physicians will become more familiar with the use of ultrasonography to guide intravenous access.[8] Although some patients will still require central venous access, using ultrasonography to achieve peripheral venous access in patients who have no other requirement for central venous access may result in decreased complications, decreased time spent obtaining intravenous access, and increased patient satisfaction.

The first case series showing the successful use of ultrasonography to guide peripheral venous access in ED patients was by Keyes et al.[7] They showed a successful cannulation rate of 91%. However, there was no control group in their study. A similar success rate of 94% was obtained by another observational study.[9] Previous studies attempting to address the subgroup of difficult-access patients without using ultrasonography used palpation of the deep brachial artery to aid in peripheral intravenous cannulation of the brachial vein, with a success rate of about 70%.[10,11]

Our current study compared ultrasonography-guided peripheral intravenous access to traditional landmark and palpation techniques. Because of previous experience with ultrasonographic-guided peripheral intravenous access, many emergency physicians were concerned about the unnecessary

placement of central lines in patients in the control arm of our study. We devised a rescue pathway in which a patient in the control arm who failed 3 additional attempts at access by an emergency physician could have an ultrasonography-guided attempt before attempting central venous access.

More than 20 physicians participated in the study. Experience ranged from no previous ultrasonography-guided peripheral intravenous placements to greater than 50 placements. The majority of physicians had little experience with ultrasonography-guided peripheral intravenous access.

Overall success rate was significantly better using ultrasonographic guidance than using traditional techniques; 97% of the patients in the ultrasonographic group had an 18-gauge catheter successfully placed in fewer than 3 attempts, which has obvious benefits for fluid administration, intravenous-medication administration, and blood collection, as well as for various diagnostic tests, such as intravenous contrast administration for suspected pulmonary embolus. In contrast, only 33% of the patients in the traditional-approach group had successful placement of an intravenous catheter. Eleven of these patients entered a rescue pathway in which they received ultrasonographic guidance for peripheral intravenous placement. All 11 of these patients had successful peripheral intravenous cannulation within 3 attempts using ultrasonographic guidance. The low success rate of the control group may be because no deep-brachial-vein cannulations were attempted in that group because of unfamiliarity with the technique. The high (>25%) complication rate of that approach may have dissuaded the inexperienced from attempting blind deep-brachial-vein catheterization.[10] A recent study comparing ultrasonography-guided peripheral intravenous access to traditional approaches found similar success rates in the ultrasonography (86%) and control (46%) groups.[12]

There was significant decrease in the amount of time to perform the procedure. We measured time to being notified by the nursing staff, as well as time to first percutaneous puncture, in an attempt to control for the presumed delay that bringing the ultrasonography machine to the patient's bedside and turning on the machine would entail. The results suggest that the time spent "searching" for a peripheral vein was quicker using ultrasonographic guidance, as well as the ability of the ultrasonography to guide the needle to successful cannulation once a percutaneous puncture was made. The quicker time to cannulation, about 11 minutes (15 minutes versus 4 minutes for ultrasonography), was even less than the difference for the total procedure time from nurse notification (a difference of 17 minutes), which suggests that the time required to set up the ultrasonography machine does not contribute significantly to the overall time spent obtaining intravenous access.

The increase in patient satisfaction with ultrasonographic guidance is probably directly related to the decreased number of percutaneous punctures in that group. However, we did notice a "wow" factor among patients who had a long history of difficult intravenous access when we brought the ultrasonography machine into the room, which may have influenced the satisfaction score.

There were no complications during the study in the ultrasonographic group. However, previous studies have found a brachial-artery-puncture rate of about 2%.[7,9] Two of the complications in the control group were neck hematomas, which can be argued are no different from any hematoma from a missed peripheral intravenous puncture, which we did not include as a complication. The limited numbers of central venous access attempts in the study limit any discussion of the role of decreased complications from using ultrasonography guidance to speculation.

We used a 2-physician technique for ultrasonographic guidance. One operator held the ultrasonography probe, and the other achieved intravenous access. In our opinion, a 1-person technique or a physician-and-nurse combination could be used with equivalent results. In current practice, we routinely use a 1- or 2-operator approach, depending on availability of personnel, with seemingly equal results. A previous study showed no difference in success with ultrasonography-guided peripheral intravenous access using either 1 or 2 operators.[13]

We also used a transverse, or short-axis, approach when using ultrasonographic guidance of the catheter, in contrast to a longitudinal, or long-axis, approach. A recent study showed the short-axis to be superior to the long-axis technique among ultrasonography novice emergency physicians in an inanimate gel model of ultrasonography-guided intravenous access.[14] Although it was not included in the current study, we expect that a long-axis approach could also be used successfully for peripheral intravenous access.

Ultrasonography-guided peripheral intravenous access is superior to traditional landmark and palpation approaches in achieving successful intravenous cannulation, decreasing the number of percutaneous punctures, decreasing time spent doing the procedure, and increasing patient satisfaction with the procedure. Ultrasonographic guidance is a useful tool for the emergency physician to have when attempting peripheral intravenous access.

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