# Ultrasonographic Guidance to Improve First-Attempt Success in Children With Predicted Difficult Intravenous Access in the Emergency Department: A Randomized Controlled Trial

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**Study objective:** We determine whether ultrasonographically guided intravenous line placement improves the rate of first-attempt success by 20% for children with predicted difficult intravenous access. Secondary objectives included determining whether ultrasonographically guided intravenous line placement reduces the attempt number, improves time to access or parental satisfaction, or affects intravenous line survival and complications.

**Methods:** This was a prospective, randomized controlled trial conducted in an urban tertiary care pediatric emergency department that enrolled a convenience sample of children requiring an intravenous line and who were predicted to have difficult intravenous access according to a previously validated score. Participants were randomized to traditional or ultrasonographically guided intravenous line placement on first attempt and stratified by aged 0 to 3 versus older than 3 years.

**Results:** One hundred sixty-seven patients were enrolled and randomized to traditional intravenous line or to a care bundle with a multidisciplinary team trained to place ultrasonographically guided intravenous lines. First-attempt success was increased in the ultrasonographically guided intravenous line placement arm (n=83) compared with the traditional intravenous line arm (n=84) (85.4% versus 45.8%; relative risk 1.9; 95% confidence interval [CI] 1.5 to 2.4). There were fewer attempts in the ultrasonographically guided intravenous line placement arm than in the traditional intravenous line arm (median 1 versus 2; median difference 1; 95% CI 0.8 to 1.2) and a shorter time from randomization to intravenous line flush (median 14 minutes [interquartile range 11 to 20] versus 28 minutes [interquartile range 16 to 42]). A Kaplan-Meier survival analysis demonstrated that ultrasonographically guided intravenous lines survived longer than traditional ones (median 7.3 days [95% CI 3.7 to 9.5] versus 2.3 days [95% CI 1.8 to 3.3]). There was no difference in complications between the groups. Parents were more satisfied with ultrasonographically guided intravenous line placement.

**Conclusion:** Ultrasonographically guided intravenous line placement in children with predicted difficult intravenous access improved first-attempt success and intravenous line longevity when conducted by a team of trained providers. [Ann Emerg Med. 2019;74:19-27.]

Please see page 20 for the Editor's Capsule Summary of this article.

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## INTRODUCTION

### Background

The need to place an intravenous line is a common but challenging requirement for pediatric health care providers. Previous research has observed first-attempt rates for pediatric intravenous line access of approximately 75%, although some children with difficult intravenous access may require multiple attempts.[1,2] Difficulty in obtaining intravenous line access may result in diagnostic and treatment delays, in addition to increased pain and anxiety for the patient and family. If intravenous line access cannot be obtained, more invasive procedures, including central or intraosseous line placement, may be required.

### Goals of This Investigation

Ultrasonographic guidance is a method used to assist with intravenous line access, but research to

**Editor's Capsule Summary**

*What is already known on this topic*

Ultrasonography is frequently used to assist the placement of a peripheral intravenous catheter, although the effect on procedural success is uncertain.

*What question this study addressed*

This study aimed to determine whether ultrasonography improved first-attempt peripheral intravenous line access success rates compared with traditional palpation methods for children with predicted difficult access.

*What this study adds to our knowledge*

In this trial of 167 children, ultrasonographically guided peripheral intravenous line placement had a higher first-attempt success rate compared with traditional methods (85% versus 46%; relative risk 1.9; 95% confidence interval 1.5 to 2.4). Physicians placed the majority of ultrasonographically guided peripheral intravenous lines with a long catheter, whereas nurses placed all of the traditional intravenous lines with a short one.

*How this is relevant to clinical practice*

Ultrasonography improved the success rates for children with presumed difficult peripheral intravenous line access. Further studies should determine the effect for nurses who place the majority of peripheral intravenous lines.

determine its efficacy in children has found mixed results. The largest trial to date found no benefit with ultrasonographic guidance compared with traditional intravenous line placement,[1] whereas one meta-analysis found a trend toward fewer intravenous line placement attempts with the use of ultrasonography.[3] We conducted a randomized controlled trial to assess the efficacy of ultrasonographically guided intravenous line placement to improve first-attempt success by 20% in children with predicted difficult intravenous line access in a pediatric emergency department (ED). The use of a clinical score previously validated to predict difficult intravenous access could identify patients most likely to benefit from the use of ultrasonographic guidance.[2,4] Secondary outcomes included time from randomization to successful intravenous line access, the number of access attempts, the duration of intravenous line survival from line flush until the line was documented as removed in the electronic health record, intravenous line complications reported in the electronic health record, and parental satisfaction with the intravenous line access process.

## MATERIALS AND METHODS

### Study Design and Setting

This was a randomized controlled trial comparing traditional intravenous line access with a bundle of care in which specially trained providers placed ultrasonographically guided intravenous lines by using predominantly longer catheters in children with predicted difficult intravenous access according to a previously validated scoring system.[4] This study was conducted in an urban tertiary care pediatric ED with greater than 95,000 annual visits. The study was approved by the hospital's institutional review board.

### Selection of Participants

Enrollment occurred when 1 of 18 study team members trained in ultrasonographically guided intravenous line placement was available to perform the study procedures. Study team members included 3 attending physicians, 10 fellows, and 5 nurses. Attending physicians and fellows were assigned to day, evening, and overnight shifts, and nurses were assigned to day or evening shifts according to routine scheduling without regard to this study. One attending physician was self-taught in ultrasonographically guided intravenous line placement; the other attending physicians and fellows completed an ultrasonographic rotation as part of their fellowship, which included training in ultrasonographically guided intravenous line placement. ED nurses, none of whom had previous ultrasonographic experience, were trained during a 4-hour didactic and hands-on session. All study members placed at least 10 supervised ultrasonographically guided intravenous lines successfully before joining the study. If a patient was randomized to traditional intravenous line access, a senior nurse (defined as a nurse with >3 years of clinical experience) who was the patient's bedside nurse or able to assist the bedside nurse placed the intravenous line according to our usual practice for patients with suspected difficult intravenous access. Consultation with the hospital intravenous line access team was allowed for the traditional intravenous line group.

Research staff screened patients who were likely to require an intravenous line according to their presenting chief complaint. Research staff identified children for potential study enrollment who were aged 0 to 18 years and required intravenous line access as determined by their treatment team. ED nurses performed a validated difficult intravenous access score as part of standard ED assessment.

Children with a score greater than or equal to 3 were eligible for this study and approached for enrollment. Exclusion criteria included critically ill patients who required emergency intravenous line access, those with previous intravenous line placement attempts during this encounter, and those whose parent or guardian did not speak English. Consent was obtained by the study team members and by select research assistants trained in obtaining informed consent.

## Interventions

After obtaining informed consent, study staff randomized the patient to an intervention group by opening a sealed envelope. Two sets of envelopes were used to stratify patients by age (0 to 3 or >3 years) to ensure balance in age groups between the study groups because younger children have higher rates of failed intravenous line access.[4] The randomization scheme was generated in advance with random-sized blocks.

If patients were randomized to traditional intravenous line access, nurses were permitted to use adjunctive methods to obtain it, including transilluminators, hot packs, or both. The nurses chose the intravenous line gauge and length in accordance with their clinical judgment.

If patients were randomized to ultrasonographically guided intravenous line placement, the line was placed by an available study team member. Ultrasonographically guided intravenous lines were placed by a single operator using the dynamic technique in the short axis, whereby the intravenous line is placed under direct ultrasonographic guidance, with the probe held in transverse position.[5] The operator scanned the patient's extremities and chose an appropriate vessel. The operator chose the intravenous line gauge and length, using his or her clinical judgment. In our ED, clinicians are encouraged to use the longer intravenous line catheters, either the 45-mm 20-gauge or 48-mm 22-gauge, for ultrasonographically guided intravenous line placements.

The use of topical lidocaine or anesthetic spray was according to provider preference and was not standardized or measured in this study.

If the intravenous line placement according to the method assigned by study randomization was not successful after the first attempt, the patient's care team could determine how to proceed. Options included a second attempt by the same method or switching methods, consulting the intravenous line team (if not previously consulted), or considering alternatives to intravenous line placement.

After the intravenous line was successfully placed or further attempts at placement had ceased, the patient's parent or guardian was asked by the research assistant to rate the child's experience with intravenous line access on a scale of 1 (worst) to 10 (best).

## Outcome Measures

The primary outcome was defined as success or failure on the initial attempt at intravenous line placement and was documented by the research assistant. Secondary outcomes included number of intravenous line access attempts as recorded by the research assistant; time to intravenous line placement from randomization as recorded by the research assistant until the line placed was flushed with 3 mL of normal saline solution, without signs of extravasation, as recorded by the research assistant; intravenous line survival from flush until the line was documented as removed in the electronic health record; and complications reported in the electronic health record. Parents were asked by the research assistants to report their satisfaction with the intravenous line access process on a scale of 1 (worst) to 10 (best) after an intravenous line was placed or the decision was made to make no further attempts at access.

## Primary Data Analysis

In accordance with previous studies of the difficult intravenous access score, we expected a 50% first-attempt success rate in the traditional group.[2,4] A focus group of ED attending physicians, fellows, and nurse practitioners determined that an increase to 70% on first-attempt success would be a clinically significant benefit to justify routine use of ultrasonography in patients with predicted difficult intravenous access. We considered that the patient's age might confound the primary outcome and thus planned to randomly assign the enrolled patients to a treatment group after stratifying by age (0 to 3 and >3 years). We assumed the same treatment difference in success rates for each age group. A sample size of 93 patients per group was calculated to achieve 80% power to detect this difference of 20% between 2 groups, using a 2-sided $z$ test without continuity correction at the significance level of .05.

We used standard descriptive statistics (mean, SD, median, interquartile range, and range for continuous variables; frequency counts and percentages for categoric variables) to describe patient characteristics and study outcomes by treatment group. The intent-to-treat population was defined as all patients originally allocated after randomization. The primary and secondary outcomes of parental satisfaction with the intravenous

line access process were analyzed with the intent-to-treat population. The denominator included all enrolled patients. The secondary outcomes of intravenous line survival from flush until the line was documented as removed in the electronic health record and complications reported in the electronic health record were analyzed by both intent to treat and type of intravenous line patients actually received. The denominator in both cases was the number of patients admitted to the hospital with intravenous line access.

The primary outcome of successful intravenous line placement at the first attempt and the secondary outcome of complications reported in the electronic health record were examined with the logistic regression models with generalized estimating equations and log-link function. These models accounted for clustering of providers. The results from these models were reported as relative risk with 2-sided 95% confidence interval (CI). The primary analysis was to test the ratio of the percentage of successful intravenous line placements at the first attempt between the 2 treatment groups. If the 95% CI of this ratio included 1, then we concluded that there was no difference between the 2 treatment groups. The quantile regression models were performed to calculate the median differences between the 2 treatment groups, with 95% CI for the secondary outcomes (number of successful intravenous line placement attempts, time from randomization to successful intravenous line access, intravenous line survival from flush until the line was documented as removed in the electronic health record, and parental satisfaction with the intravenous line access process).

Kaplan-Meier survival analysis was used to generate survival curves and to estimate survival data for the time of successful intravenous line placement from randomization to flush and, for the patients admitted to the hospital with a study intravenous line, intravenous line survival from flush until the line was documented as removed in the electronic health record both by the intravenous line type received and by intent to treat. Cox proportional regression models adjusting for clustering (providers) were performed to investigate the differences in time to event variables between the 2 treatments groups. We generated all figures, summaries, and statistical analyses with Stata (version 15.0; StataCorp, College Station, TX).

## RESULTS

### Characteristics of Study Subjects

We screened 1,926 patients from June 2014 to December 2016 and approached 206 eligible patients. Patients were screened by the research assistants according to chief complaints that frequently required an intravenous line placement. Many patients who were screened did not ultimately require an intravenous line, and many of those who required one did not have eligible difficult intravenous access scores. One hundred sixty-seven patients (73%) gave consent for enrollment and were randomized after stratification by age group (Figure 1). The study was stopped early because, as more providers became trained in ultrasonographically guided intravenous line placement, intravenous access obtained by nurses, fellows, or attending physicians became standard of care in our ED for patients

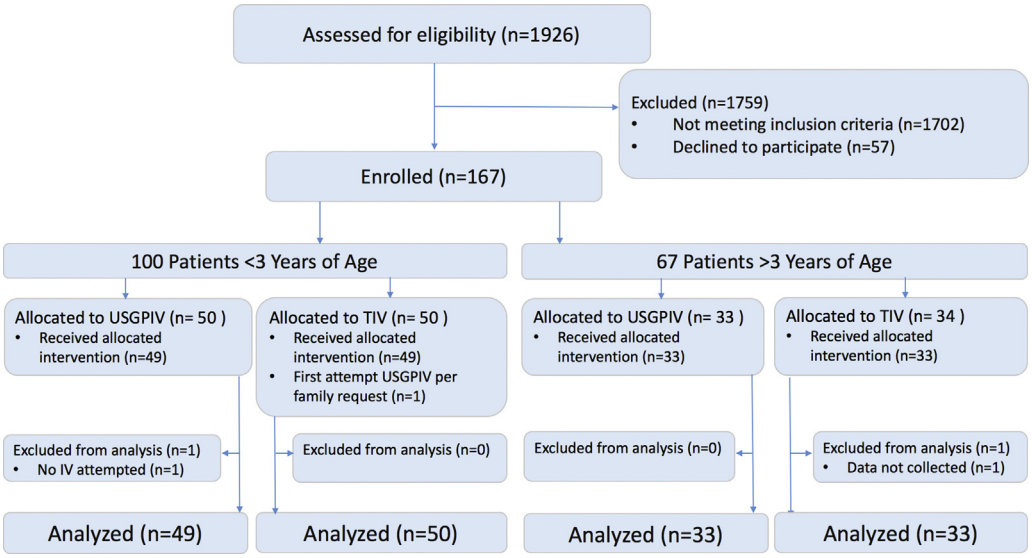


**Figure 1.** Flow diagram. *USGPIV*, Ultrasonographically guided IV line placement; *TIV*, traditional intravenous line; *IV*, intravenous line.

with presumed difficult intravenous line access before analysis of results from this study.

There were 167 patients enrolled in the study (Figure 1). One patient in the group aged 0 to 3 years who was randomized to ultrasonographically guided intravenous line placement was found not to need an intravenous line after randomization. In the traditional intravenous line group, 2 patients, one in the group aged 0 to 3 and the other in the group older than 3 years, requested an ultrasonographically guided intravenous line placement after randomization to traditional intravenous line. The patient in the older than 3 years group who requested ultrasonographically guided intravenous line placement had no data collected on the intravenous line placement attempts. One patient in the group aged 0 to 3 years who was randomized to traditional intravenous line withdrew after the first attempt.

In the traditional intravenous line group, 56 nurse providers attempted the first intravenous line placement. In the ultrasonographically guided intravenous line group, there were 17 providers, including 4 nurses who attempted the first intravenous line placement. The median number of patients per nurse in the traditional intravenous line group was 1 (range 1 to 5); in the ultrasonographically guided intravenous line group, the median number of patients per nurse was 2 (range 1 to 5).

The study groups were similar in age, sex, race, and ethnicity (Table 1). The median age was 2.1 years in both groups.

**Main Results**

The first-attempt success was 45.8% in the traditional intravenous line group and 85.4% in the ultrasonographically guided intravenous line group (Table 2). The relative risk for first-attempt success was 1.9 (95% CI 1.5 to 2.4). For every 3 ultrasonographically guided intravenous line placement attempts, 1 missed attempt was prevented compared with that for a traditional intravenous line.

The median number of attempts was 1 (interquartile range 1 to 1) in the ultrasonographically guided intravenous line group and 2 (interquartile range 1 to 2) in the traditional intravenous line group (median difference 1; 95% CI 0.8 to 1.2). By the third attempt, the percentage of successfully placed intravenous lines was 89.2% in the traditional intravenous line group and 97.6% in the ultrasonographically guided intravenous line group, although 17 patients in the traditional intravenous line arm ultimately had an ultrasonographically guided intravenous line placed, whereas only 3 patients from the ultrasonographically guided intravenous line group ultimately had a traditional intravenous line placed (Table 2). The clinicians placing the intravenous line chose the type of line to place and its location. Traditional intravenous lines were most often placed in the hand (71%), followed by the antecubital fossa (15%), whereas most of the ultrasonographically guided intravenous lines were placed in the forearm (93%). The majority of the ultrasonographically guided intravenous line placements (90% [87/97]) used the longer 45-mm 22-gauge or 48-mm

**Table 1.** Patient characteristics by treatment group.

| Characteristics | TIV (n=84) | Ultrasonographically Guided IV Line Placement (n=83) | Total (n=167) |
|---|---|---|---|
| **Age, y** | | | |
| Mean (SD) | 5.0 (5.54) | 5.6 (5.97) | 5.3 (5.75) |
| Median (IQR) | 2.1 (0.8–8.5) | 2.1 (0.99–11.5) | 2.1 (0.85–10.8) |
| Range | 0.01–17.8 | 0.13–17.7 | 0.01–17.8 |
| **Age, No. (%), y** | | | |
| 0–3 | 50 (59.5) | 50 (60.2) | 100 (59.9) |
| >3 | 34 (40.5) | 33 (39.8) | 67 (40.1) |
| Male patients, No. (%) | 39 (46.4) | 43 (51.8) | 82 (49.1) |
| **Race, No. (%)** | | | |
| Black | 38 (45.2) | 38 (45.8) | 76 (45.5) |
| Asian | 4 (4.8) | 5 (6.0) | 9 (5.4) |
| White | 36 (42.9) | 31 (37.3) | 67 (40.1) |
| Other | 6 (7.1) | 9 (10.8) | 15 (9.0) |
| Ethnicity, Hispanic, No. (%) | 6 (7.2) | 10 (12.0) | 16 (9.6) |

*IQR*, Interquartile range.

**Table 2.** Cumulative success by attempt analyzed by intention to treat

| | First Attempt | | | Second Attempt | | | Third Attempt | | |
|---|---|---|---|---|---|---|---|---|---|
| **Group** | **TIV** | **USGPIV** | **Total** | **TIV** | **USGPIV** | **Total** | **TIV** | **USGPIV** | **Total** |
| **0-3 y, No. (%)** | 23 (46.0) | 40 (81.6) | 63 (63.6) | 39 (79.6) | 45 (91.8) | 84 (84.8) | 44 (89.8) | 47 (95.9) | 91 (91.9) |
| **>3 y, No. (%)** | 15 (45.5) | 30 (90.9) | 45 (68.2) | 24 (72.7) | 33 (100.0) | 57 (86.4) | 30 (90.9) | 33 (100.0) | 63 (95.5) |
| **Total, No. (%)** | 38 (45.8) | 70 (85.4) | 108 (65.5) | 63 (75.9) | 78 (95.1) | 141 (85.5) | 74 (89.2) | 80 (97.6) | 154 (92.8) |

Eighty-four subjects were randomized to TIV, 83 were analyzed (50 of them were 0 to 3 years of age); 83 subjects were randomized to USGPIV, 82 were analyzed (49 of them were 0 to 3 years of age).

20-gauge catheters. The majority of the traditional intravenous lines (57/62) were placed with regular 25-mm 22-gauge or 19-mm 24-gauge intravenous lines. There was 1 traditional intravenous line placed with a longer 45-mm 22-gauge intravenous line and 3 placed with shorter 14-mm 24-gauge catheters.

Kaplan-Meier survival analysis for the time to successful intravenous line placement is shown in Figure 2. The median time of successful intravenous line placement from randomization to flush was 28 minutes (95% CI 21 to 31 minutes) in the traditional intravenous line group and 14 minutes (95% CI 13 to 15 minutes) in the ultrasonographically guided intravenous line group.

The first-attempt success was examined by the training level of the study team members. Three attending physicians attempted 28 ultrasonographically guided intravenous line placements, with a 100% success rate. Ten fellows attempted 43 ultrasonographically guided intravenous line placements, with a 74% first-attempt success rate. Three nurses had a 91% first-attempt success rate for the 11 ultrasonographically guided intravenous line placements they attempted.

After the intravenous line was placed, parents were asked to score their satisfaction with the intravenous line placement process on a scale of 1 to 10. Response rates were 77 of 83 in ultrasonographically guided intravenous line group and 76 of 84 in traditional intravenous line group. Parents were more satisfied with ultrasonographically guided intravenous line placement compared with traditional placement (median 10 [interquartile range 8 to 10] versus 8 [interquartile range 5 to 10]; median difference 2 [95% CI 0.9 to 3.1]).

Of the 167 patients enrolled in the study, 123 were admitted to the inpatient service with peripheral intravenous lines. These lines were tracked in the electronic health record, and 85% of the patients had a documented removal time. After censoring for intravenous lines that were no longer needed, those lost to follow-up, and those without a documented removal reason, the Kaplan-Meier survival analysis by the type of intravenous line received demonstrated a median line survival from flush until the line was documented as removed in the electronic health record of 2.3 days (95% CI 1.8 to 3.3 days) in the traditional intravenous line group compared with 7.3 days (95% CI 3.7 to 9.5 days) in the ultrasonographically guided intravenous line group (Figure 3). The Kaplan-Meier survival analysis by intent to treat revealed a survival time of 2.6 days (95% CI 1.9 to 4.5 days) in the traditional intravenous line group versus a survival time of 4.5 days (95% CI 3.5 to 9.3 days) in the ultrasonographically

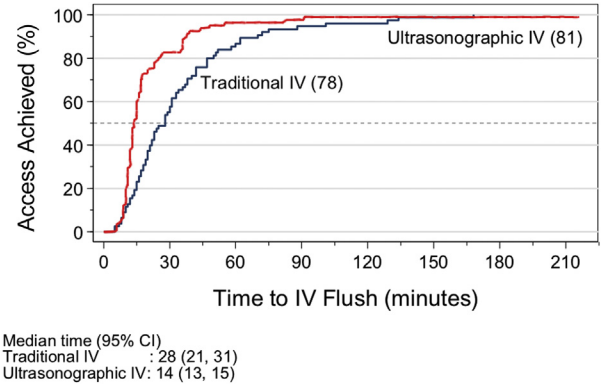


**Figure 2.** Time to successful intravenous line placement (intent to treat).

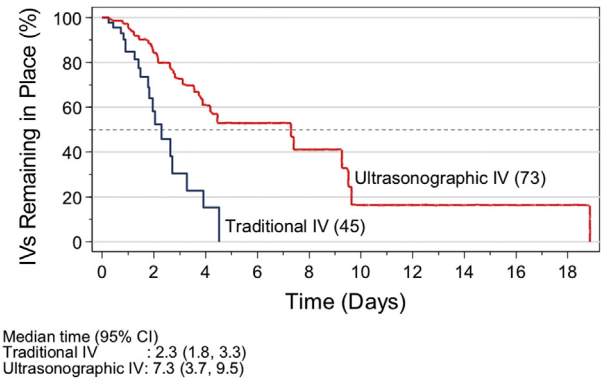


**Figure 3.** Time to complication (type of intravenous line actually received).

guided intravenous line group (Figure E1, available online at http://www.annemergmed.com).

There were no serious complications reported with intravenous line placement. In patients admitted with a peripheral intravenous line, there were 19 complications reported from the 40 traditional intravenous lines (48%; 95% CI 34% to 66.5%) and 26 complications reported from the 65 ultrasonographically guided intravenous lines (40%; 95% CI 30% to 53%) (relative risk 0.84; 95% CI 0.53 to 1.34). Complications included phlebitis, infiltration, pain, leakage, bleeding, unintentional dislodgement, and line occlusion. There were no differences in the type of complications reported as reasons for intravenous line removal between the 2 groups.

### Limitations

This study was limited to a single center. It randomized patients to standard care with traditional intravenous line access to a bundle of care in which trained providers placed ultrasonographically guided intravenous lines, using predominantly longer catheters. These results may not be generalizable to other groups of providers or methods of intravenous line placement. Nurses now place the majority of ultrasonographically guided intravenous lines in the ED but were underrepresented in this study in part because it was conducted as nurses were being trained to place ultrasonographically guided intravenous lines. This meant that there were few nurses initially who were qualified to participate. Many nurses declined to become study team members because they were asked to also obtain informed consent for the study, which they were not comfortable doing. Although the nurses were instructed to screen all patients for difficult intravenous access in the ED, they may not have reported all of the patients with elevated difficult intravenous access scores to the research assistant, which may have resulted in selection bias. The subjects were not blinded to the treatment they received, which may have affected their satisfaction with the intravenous line type they received. Satisfaction measurements, asked by a research assistant after the patient had an intravenous line placed, may not be reliable. In particular, families may believe that the use of new technology such as ultrasonography enhances their care, biasing them toward a preference for ultrasonographic use. We did not assess for reasons for nonresponse to the satisfaction survey, and there were 6 (of 83) missing responses in the ultrasonographically guided intravenous line group and 8 (of 84) in the traditional intravenous line group, which may have affected our results. The study was also stopped before enrollment of 93 patients per group because ultrasonographically guided intravenous line placement became standard of care in the ED.

## DISCUSSION

This study found that ultrasonographically guided intravenous line placement improved first-attempt success in obtaining intravenous line access in children with presumed difficult access. An earlier investigation into whether ultrasonographically guided intravenous line placement access or near-infrared imaging could improve first-attempt success compared both those methods with standard technique in all children.[1] The authors enrolled 418 patients younger than 16 years who required an intravenous line as part of their care. The study found no difference in first-attempt success between children randomized to traditional technique versus ultrasonography or near-infrared imaging. This implies that for pediatric patients in the ED who do not have presumed difficult intravenous line access, when first-attempt success rates of traditional intravenous lines are approximately 75%, there may be little benefit to using to ultrasonography to aid in intravenous line placement.[1,2]

However, a meta-analysis of small randomized controlled trials comparing ultrasonographically guided intravenous line placement with traditional intravenous line access showed a trend toward fewer placement attempts in the ultrasonographic group.[3] Two of the included studies examined patients in the pediatric ED who had known difficult intravenous line access. Doniger et al[6] randomized 50 children younger than 10 years with a reported history of difficult intravenous access or 2 failed peripheral intravenous line placement attempts to ultrasonographically guided or traditional intravenous line access. Ultrasonographically guided intravenous line placement in that study involved a dynamic dual-operator technique in which the physician conducted the ultrasonography while the nurse cannulated the vein. The study was stopped early because of inadequate enrollment. Although it did not meet statistical significance, there was a trend toward increased success with ultrasonographically guided intravenous line access. The other study, by Bair et al,[7] compared standard intravenous line access with ultrasonographically guided intravenous line access in 44 children younger than 7 years who had 1 previous failed traditional intravenous line placement attempt. This study differed from ours in that it used a static ultrasonographic technique in which the vein was identified, marked, and then cannulated without the use of ultrasonography. The study found no difference in cannulation success between the 2 arms. The use of the static technique as opposed to the dynamic technique used in our study may account for the different study results.

In the adult population, concerns exist in regard to the longevity of placements of ultrasonographically guided intravenous lines. Fields et al[8] reported a 32% failure rate at 48 hours. In our study of children, ultrasonographically guided intravenous lines remained in place longer than the traditional ones, without an increase in the number of complications reported. In this study, only 20% of the intravenous lines had failed by 48 hours (Figure 3). This may be explained by the location chosen for intravenous line placement. Fields et al[8] found that vessel depth and location affected intravenous line survival: ultrasonographically guided intravenous lines placed in more shallow vessels survived significantly longer than those placed in deeper vessels, and those placed in the antecubital fossa or forearm survived longer than those placed in the upper arm.[8] The majority of the ultrasonographically guided intravenous lines in our study were placed in the forearm. Although vessel depth was not measured in this study, the forearm veins are likely more superficial in children, who are generally smaller than adults; as such, many of the ultrasonographically guided intravenous lines are likely to have been placed in shallow vessels. Last, most of the ultrasonographically guided intravenous lines placed in our study used the longer catheters. This suggests that more of the catheter was seated within the vein, which may in turn have resulted in increased intravenous line duration.

Analysis across provider types showed increased levels of success with ultrasonographically guided intravenous line placement above predicted rates for patients with difficult intravenous access with traditional intravenous lines, including for fellows with less experience in placing intravenous lines. Attending physicians and nurses may have had higher success rates than fellows because of more experience with placing ultrasonographically guided intravenous lines. Although all study team members had successfully placed at least 10 ultrasonographically guided intravenous lines previously, exact data on how many lines each provider had placed before this study were not available. The high rates of nurses' success led to a training program in our ED to broadly train nurses in ultrasonographically guided intravenous line placement, which has become standard procedure for patients with presumed difficult intravenous access.

In summary, in our randomized trial, ultrasonographically guided intravenous line placement in children with predicted difficult intravenous access by experienced providers improved first-attempt success rates, reduced the time to placement, and decreased the overall number of attempts. Furthermore, ultrasonographically guided intravenous lines lasted longer and were not found to cause more complications than traditional ones. Parental and patient satisfaction were significantly higher for patients randomized to the ultrasonographically guided intravenous line group. These results may be used to update guidelines for intravenous line access in children in an effort to limit the number of needlesticks they experience.

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*Author contributions:* AMV, AEC, and JJZ conceived the study and designed the trial. All authors supervised the conduct of the trial and data collection and contributed substantially to article revision. OUE analyzed the data and assisted with writing the analyses and results section. JJZ provided statistical advice on study design. AMV and JJZ analyzed the data. AMV drafted the article. AMV takes responsibility for the paper as a whole.

All authors attest to meeting the four ICMJE.org authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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IMAGES IN EMERGENCY MEDICINE

*(continued from p. 17)*

**DIAGNOSIS:**

*Acute cervical implant extrusion with anteriorly displaced plate and surgical fixation screws*. Radiograph of the cervical spine demonstrated separation of the plate and associated surgical fixation screws from the respective vertebral bodies (C4 through C7). The patient was admitted for operative hardware revision. Postsurgical outcome was ultimately improved compared with preprocedural baseline.

Complications of anterior cervical spine procedures include dysphagia, esophageal perforation, dural penetration, recurrent laryngeal nerve palsy, hematoma formation, and wound infection.[1]

Two-year revision rates for anterior cervical decompression and fusion in one study were 2% to 9% for single-level fusions and 4% to 10% for multilevel ones, and most commonly as a result of adjacent segment disease.[2] Acute mechanical hardware failure is a rare complication, reported in less than 1% of cases and typically occurring within a month of the index operation according to a large retrospective multicenter study.[3] Although aggravation of preexisting myelopathy can rarely occur, the majority of patients should be expected to experience relief from myelopathy symptoms postoperatively. As such, residual, recurrent, or increased myelopathic symptoms should prompt consideration of potential acute complications such as hardware failure, which may be revealed by radiographs or advanced imaging modalities.

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