



Original Contributions

PREDICTING FAILURE OF INTRAVENOUS ACCESS IN ADULTS: THE VALUE OF PRIOR DIFFICULTY

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Abstract—Background: When intravenous access cannot be established using traditional methods of inspection/palpation, advanced methods are often required, leading to substantial delays in care. Knowing the likelihood of intravenous access failure can improve emergency department (ED) efficiency. **Objective:** Our aim was to validate prior need for an advanced technique to establish intravenous access as a predictor of failure to achieve access via traditional methods and to estimate the risk difference associated with this finding. **Methods:** We re-analyzed data collected for a clinical trial that randomized ED patients requiring intravenous access to one of two types of intravenous catheter; gauge size was selected by the inserter. The re-analysis pools data from both groups to examine predictors of failure to establish intravenous access by traditional methods, with *failure* defined as abandonment or use of an advanced technique (ultrasound guidance or external jugular vein catheterization). Confidence intervals for the difference between proportions were calculated using a normal binomial approximation. **Results:** We obtained data from 600 patients, with a median age of 52 years (interquartile range 36–63 years). We noted failure of traditional methods in 28 (4.7%) patients, including 17 of 109 (16%) with prior need for advanced techniques. The risk difference for prior need for advanced techniques versus no prior difficulty was 14% (95% confidence interval 7–22). **Conclusions:** Patients with a prior need for advanced techniques were 14% more

likely to have failure of intravenous access by traditional methods than those without prior difficulty. © 2019 Elsevier Inc. All rights reserved.

Keywords—catheterization; peripheral intravenous; catheterization; emergency service; hospital; crowding; decision-making

INTRODUCTION

Intravenous access is a vital part of emergency care, but providers experience difficulty obtaining access in some patients. In severe cases, patients wait hours for intravenous access, delaying their care and consuming valuable resources, such as emergency department (ED) space and time for staff members to work at establishing access (1,2). In some cases, attempts to establish intravenous access represent wasted effort because many lines that are inserted go unused (3,4). The waste of time, space, and equipment, in addition to the effects on patient care, are particularly problematic in this era of ED crowding and interest in cost containment.

Difficult intravenous access has been defined as requiring multiple attempts or operators. However, the type of difficulty that results in the longest delay is the need for an advanced technique (5,6). Virtually all emergency care providers have the skills to obtain intravenous access using traditional methods of inspection/

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palpation of peripheral veins, but relatively few are able to use advanced techniques, such as external jugular vein access, ultrasound guidance, or central vein catheterization. Failure to establish intravenous access by traditional methods leads to substantial delays because someone skilled in an advanced technique must be summoned to the bedside.

Knowing which patients are likely to require advanced intravenous access techniques may allow more efficient use of ED resources. Early identification of such patients could prompt a decision to either manage the patient without committing to intravenous access or alert the ED team that an advanced method might be needed. According to a case-control study, one predictor of failure of intravenous access by traditional methods is a prior need for advanced techniques (1). In the current study, we used data collected during a clinical trial to validate prior need for advanced techniques as a predictor of failure to gain intravenous access by traditional methods.

MATERIALS AND METHODS

Study Design

This report is based on a secondary analysis of data collected for a randomized clinical trial that compared a flash-tip catheter with a traditional catheter (7). We obtained approval for this study from our Institutional Review Board.

Study Setting and Participants

We enrolled participants at an urban university-affiliated community hospital with 65,000 annual visits, collecting data between June and October of 2016. Inclusion criteria were as follows: requiring intravenous access for clinical care, aged older than 17 years, hemodynamically stable, and able to provide verbal informed consent. Enrollment occurred at times when a research assistant (a nurse or medical student) or the principal investigator was available. Exclusion criteria were medical instability, agitation or psychological instability, inability to speak English, and altered mental status.

Data Collection

After enrollment, we collected baseline data, which included age, sex, operator type (nurse, physician, or technician), operator experience in years, catheter gauge selected, and prior patient intravenous experience. We categorized prior intravenous access experience, as no prior intravenous line insertion attempts, prior attempts with no difficulty, mild difficulty (requiring multiple skin punctures or operators), or moderate difficulty (requiring

an advanced technique, such as external jugular vein access, ultrasound guidance, or central venous access). We also documented whether the initial intravenous attempt was successful, whether advanced techniques were needed, and whether intravenous access was abandoned, meaning that the physician or patient decided to discontinue trying to establish access after the initial attempt.

Data Analysis

Our primary outcome was the proportion of patients in whom intravenous access could not be established by traditional methods of inspection/palpation. Attempts were considered failures of traditional methods if an advanced technique was required to start an intravenous line or if efforts to establish intravenous access were abandoned after the first attempt. To simplify the presentation of results, we combined data from the first two categories—no prior attempts and prior attempts with no difficulty—into one category, “no prior difficulty.” We calculated confidence intervals (CIs) for differences between proportions using a normal binomial approximation.

To examine the potential for confounding, we also analyzed associations of other variables (age, sex, operator experience, operator type, catheter type, catheter gauge) with prior difficulty and with failure to establish intravenous access via traditional methods. We examined continuous variables using histogram analysis and categorical variables by comparing subgroups with sufficient numbers head-to-head. For these comparisons, we considered $p < 0.05$ as statistically significant, using t -tests or χ^2 as appropriate. For variables associated with both prior difficulty and failure of inspection and palpation, we used a stratified analysis to examine the potential for interaction or confounding. We used the Breslow-Day test to test for interaction, and comparison of crude odds ratios with Mantel-Haenszel common odds ratios to test for confounding. We performed these calculations using OpenEpi, version 3.01 (8).

RESULTS

Characteristics of the study population and initial intravenous line insertion attempts ($n = 600$) are shown in Table 1. The majority of operators had more than 4 years of experience; all but one were technicians or registered nurses.

Table 2 shows the relationship between prior difficulty and current failure of traditional methods. Overall, attempts using traditional methods failed in 28 of 600 (4.7%) patients. Twelve patients never had an intravenous line insertion before and none of them had failed attempts via traditional methods during the trial. We combined these with the larger group that had previous intravenous line insertion with no difficulty. As the table shows, prior need

Table 1. Characteristics of Study Population and Initial Intravenous Attempts (n = 600)

Characteristics	Data
Age, y, median (IQR)	52 (36–63)
Female, n (%)	376 (63)
Intravenous gauge, n (%)	
22	214 (36)
20	381 (63)
18	5 (1)
Operator type, n (%)	
Technician	386 (64)
Registered nurse	213 (36)
Physician	1 (0.2)
Operator experience, n (%)	
≥10 y	206 (34)
5–9 y	106 (18)
1–4 y	246 (41)
<1 y	42 (7)

IQR = interquartile range

for an advanced technique was predictive of failed attempts to establish intravenous access via traditional methods.

Among the other variables examined (patient age, operator experience, operator type, catheter type, catheter gauge), only catheter gauge was statistically associated with failure of establishment of intravenous access by inspection and palpation. The risk of failure was higher when a 22-gauge catheter was chosen (21/214 [10%]) than when a 20-gauge catheter was chosen (7/381 [2%]), with a risk difference of 8% (95% CI 3–13%). Device gauge was also associated with prior difficulty, which was present in 42 of 381 (10%) attempts with 20-gauge catheters versus 66 of 214 (31%) attempts with 22-gauge catheters. Stratified analysis examining the effect of gauge on the association between prior difficulty (none versus moderate) and failure of inspection and palpation showed no interaction and similar crude versus adjusted odds ratios (16.8 versus 15.7).

DISCUSSION

This study confirms that prior need for an advanced technique for intravenous line insertion is predictive of the failure of subsequent attempts to gain intravenous access using traditional methods. Patients with a prior need for

advanced techniques experienced failure of intravenous access by inspection and palpation in 15.6% of cases versus 2% in other groups. This study also provides additional data on the epidemiology of difficult intravenous access. Overall, traditional methods failed in 4.7% of cases of attempted intravenous access.

Earlier studies that examined difficulty in establishing intravenous access defined difficulty as failure of a first attempt (9–13). This definition is the basis of the DIVA (Difficult Intravenous Access) score, which was developed and validated for children (9,10). Other studies have examined factors that predict first-attempt failure in adults (11,12). The need for additional attempts increases pain levels for patients and can decrease confidence in the treatment team (13,14). First-attempt failure particularly increases anxiety in young children. Factors associated with first-attempt failure in adults include prior difficulty, obesity, and operator inability to palpate or visualize a peripheral vein (11,12).

In adults, waiting time may be more important than the anxiety and pain associated with multiple attempts, particularly when waiting times are prolonged by crowding. To minimize wait times, predicting the failure of intravenous access via traditional methods is more important than predicting first-attempt failure. Repeated attempts using inspection and palpation result in delays estimated at 5 min if by the same provider, or 15 min if a second provider is needed (6). Patients requiring advanced techniques tend to wait for hours (with a median delay of 2 h or more), and skilled providers devote 12–20 min to each attempt, depending on the technique being used (1,5,6,15). Previous investigators, using a need for advanced techniques to define intravenous access difficulty, have found that prior need for advanced techniques and a history of intravenous drug abuse predicted difficulty, while obesity did not (1,16). Our study confirms that those with a prior need for advanced techniques are at risk of failing intravenous access by traditional methods, and it quantifies this risk.

Knowing that attempts to gain intravenous access with traditional methods are likely to fail may allow better decision-making early in a patient's stay. Because some patients can be evaluated and managed without an

Table 2. Risk of Failure of Inspection and Palpation Associated With Levels of Prior Difficulty

Prior Experience	Required Advanced,* n (%)	Abandoned,† n (%)	Combined Failure of I + P, n (%)	Risk Difference (95% CI), %
No difficulty	1/332 (0.3)	4/332 (1.2)	5/332 (1.5)	—
Mild difficulty‡	3/159 (1.9)	3/159 (1.9)	6/159 (3.8)	2 (–1 to 6)
Moderate difficulty§	9/109 (8.3)	8/109 (7.3)	17/109 (15.6)	14 (7 to 22)

I + P = inspection and palpation.

* Required an advanced technique, such as external jugular vein access, ultrasound guidance, or central venous access.

† Attempts to gain intravenous access were abandoned after initial failure.

‡ Mild difficulty is defined as prior need for multiple punctures or operators.

§ Moderate difficulty is defined as prior need for advanced techniques.

intravenous line, knowing that insertion is likely to require advanced techniques may lead a provider to avoid ordering laboratory tests, intravenous therapy, or imaging with intravenous contrast, if none of these is clearly needed. When a patient clearly requires intravenous access, anticipating a risk of failure enables the treatment team to be ready to mobilize resources to provide more timely access. However, because 92 of our 109 (86%) patients with prior moderate difficulty were still able to have successful intravenous access by traditional methods, prior moderate difficulty with intravenous access should have a minor effect on decisions of whether to order an intravenous line or divert personnel.

This study also provides additional data on the epidemiology of difficult intravenous access. A prior study based on retrospective data estimated that advanced techniques were needed in 3.2% of patients requiring intravenous access (17). The current study, which included patients in whom attempts at intravenous access were abandoned, found that advanced techniques were needed in 13 of 600 (2.2%) and that attempts at intravenous access were abandoned in 15 of 600 (2.5%), with a combined failure of traditional methods in 4.7%. It should be noted that these results were obtained in an inner-city population; the incidence may differ in rural settings.

The use of smaller-gauge catheters was associated with increased rates of failure by traditional methods, which is likely associated with the selection of smaller gauges for patients in whom difficult access was anticipated. Adjustment for this factor did not affect our estimation of the effect of prior experience.

Limitations

One limitation of this study is that we did not examine a history of prior severe difficulty. We found that any history of advanced techniques somewhat increased the risk of failure to attain intravenous access via traditional methods. It is possible that patients with greater levels of prior difficulty, such as multiple prior needs for advanced techniques or requiring them in most cases, would have a greater risk of failure of traditional methods. Another limitation is that we did not examine the effects of initial inspection alone on the likelihood of failure using traditional methods; it is likely that patients with visible veins without a tourniquet will have a lower likelihood of failure than those without visible veins. Future studies should examine the effect of these factors on risk of failure to achieve intravenous access with traditional methods.

CONCLUSIONS

A patient's history of requiring advanced techniques to establish intravenous access is a predictor of failure of

subsequent attempts to gain access with traditional methods, increasing the risk by 14% (95% CI 7–22%). Overall, attempts to gain intravenous access by traditional methods fail in 4.7% of cases.

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ARTICLE SUMMARY

1. Why is this topic important?

Failure to gain intravenous access by traditional means of inspection/palpation can lead to substantial delays in care. Predicting the likelihood of failure to gain intravenous access via traditional methods can help emergency physicians decide which patients can be managed without intravenous access and mobilize resources for others who require timely access.

2. What does this study attempt to show?

This study uses data collected in a trial setting to estimate the risk of failure to gain intravenous access by traditional methods associated with a prior need for advanced techniques (peripheral ultrasound-guidance, external jugular access, central venous access). It also estimates the incidence of failure of intravenous access by traditional methods.

3. What are the key findings?

Prior need for advanced techniques was associated with a 14% (95% confidence interval 7–22) increase in the risk of failure to establish intravenous access via traditional methods. Overall, traditional methods of intravenous access failed in 4.7% of patients.

4. How is patient care impacted?

In patients with equivocal indications for intravenous access, knowledge of a prior need for an advanced technique may sway physicians toward management without an intravenous line. For patients with a clear need for intravenous access, knowledge of a prior need for an advanced technique can alert physicians to anticipate possible failure to achieve access by traditional methods.