PREDICTORS OF SUCCESS IN NURSE-PERFORMED ULTRASOUND-GUIDED CANNULATION

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Abstract—The objective of this study was to characterize factors affecting the success rate of nurse-performed ultrasound (US)-guided peripheral vein cannulation in difficult access patients. We prospectively enrolled patients who had two previous unsuccessful i.v. attempts. Nurses were trained in US-guided cannulation using a 7.5-MHz linear probe. The following characteristics were recorded: 1) reason for difficult access, 2) which upper arm veins could be sonographically visualized, 3) cannulation success, and 4) one- or two-person technique used. One hundred patients were enrolled. The cannulation success rate was 63%. Cannulation of the basilic vein was successful in 39 of 55 attempts (71%), whereas the success rate for the brachial vein was only 19 of 46 attempts (41%). The reason for difficult access and the one- or two-person technique did not affect success rate. The basilic vein was the best choice for cannulation, and the one-person technique was as successful as the two-person technique. © 2007 Elsevier Inc.

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INTRODUCTION

It is often difficult to obtain peripheral venous access in patients who have a history of intravenous (i.v.) drug use, a medical problem requiring multiple previous i.v. cannulations, or obesity. These patients are often subjected to numerous unsuccessful peripheral i.v. attempts, followed by physician-performed central venous access, resulting in lost nursing and physician time. Previous studies have shown that emergency physicians and emergency nurses can be proficient in performing ultrasound (US)-guided peripheral venous cannulation in these patients, with success rates of 87–92% (1–3).

Although proficiency was demonstrated, the studies did not address what characteristics might contribute to differences in cannulation success rate. First, the veins of the upper arm have very different characteristics that might affect success rate. The basilic vein, although not as superficial and easy to access as the cephalic or median antecubital veins, is often larger and more likely to be sonographically visible. The brachial vein, although thought to be more universally present, is deep and in close proximity to the brachial artery and nerve (Figure 1). Second, the reason for difficult venous access, such as i.v. drug use or obesity, may affect the rate of successful cannulation. Finally, the cannulation success rates might be dependent upon whether a one- or two-person technique is utilized.

The purpose of this study was to determine how the choice of vein, the reason for difficult access, or the one- vs. two-person technique affected the success rate of nurse-performed US-guided i.v. cannulation in patients with difficult i.v. access.
MATERIALS AND METHODS

Study Design

This was a prospective observational study of a convenience sample of patients needing peripheral venous cannulation who had difficult venous access.

Setting and Population

The study was conducted at an urban, academic medical center with an annual Emergency Department (ED) census of 60,000, which serves a largely low-income population. Before the study, US-guidance for peripheral venous cannulation was not used by nurses, and such patients were candidates for physician-performed central venous access.

Study participants were patients who had at least two previous unsuccessful peripheral venous cannulation attempts, and had no other visible vein to use for further attempts. Enrollment occurred between May 2004 and June 2005. All patients were older than 17 years. The hospital’s institutional review board approved this study.

Training and Data Collection

A SonoSite iLook® 25 (SonoSite Inc., Bothell, WA) with 7.5-MHz linear array probe was used for all procedural imaging. Nurses performing US-guided cannulation completed a 90-min training session that consisted of didactic lecture, hands-on use of the ultrasound machine, and ultrasound-guided cannulation of a venous access model. The nurses were trained in only the short-axis approach (long axis of probe oriented perpendicular to long axis of the arm), as a previous study demonstrated superiority to the long-axis approach in novice sonographers (4). Nurses were trained in both the one-person technique, in which the nurse held the ultrasound probe in one hand while cannulating with the other, and the two-person technique, in which a separate person held the probe while the nurse attempted cannulation.

After obtaining consent, the nurse documented the perceived reason for difficult venous access as either: 1) i.v. drug use, 2) obesity, 3) medical problem requiring multiple previous i.v. cannulations, or 4) unknown. More than one reason for difficult access could be documented. A data collection item that was added late to the study (only for the final 74 patients) was to note if the patient had needed central venous access in the past. If the patient was unsure, it was documented as no previous central venous access. The nurses then performed an ultrasound examination of the upper arm, and documented whether the following veins were sonographically visible: 1) basilic, 2) brachial, 3) median antecubital, and 4) cephalic (Figure 1). Any vein sonographically visible in the antecubital fossa (except the deeper brachial vein) was considered to be median antecubital. The nurses documented two data items relating to cannulation: 1) ability to get a “flash” of blood and 2) cannulation...
success. Similar to another article on nurse-performed US-guided cannulation, we defined cannulation as successful if the catheter remained in place until the completion of therapy. If the catheter fell out or infiltrated before the completion of therapy, cannulation was considered unsuccessful. If there was no vein sonographically visible or none considered to be adequate for cannulation, no cannulation was attempted, and it was recorded as a cannulation failure. Standard length and 1.88-inch length angiocatheters were made available for use on the machine. Nurses made an independent determination of which vein to attempt to cannulate, how many attempts to make, what size and length catheter to use, and whether to use a one-person or two-person technique. Complications were noted on the data form according to the following categories: 1) arterial puncture, 2) numbness, or 3) severe pain.

The primary outcomes were cannulation success rates based on vein type, reason for difficult access, one-versus two-person technique, overall patients, and overall attempts.

In patients in whom US-guided cannulation was not successful, charts were reviewed to determine if other cannulation was successful. These cannulation attempts were categorized as 1) standard peripheral venous cannulation, 2) physician-performed central venous cannulation, 3) no further cannulation attempts, or 4) unknown.

Cannulation success rates were calculated with 95% confidence intervals (CIs). Exact 95% confidence intervals were calculated by the method of Clopper and Pearson using the online calculator at http://members.aol.com/johnp71/confint.html, which is part of the Interactive Statistical Pages web site (http://StatPages.net).

RESULTS

Study Subjects

Characteristics of the study group are reported in Table 1. The reason cited for difficult venous access was evenly divided between intravenous drug abuse (IVDA) and multiple previous medical procedures, with 17% of patients having two or more reasons cited. Fifty-one of 74 (69%) patients asked had required central venous access on a past visit. The brachial and basilic veins were the most often visualized, and the basilic was most often chosen for a cannulation attempt (Table 1). The nurses also chose the one-person cannulation technique four times more frequently than the two-person technique, despite the fact that a second person was nearly always available.

Main Results

The patient cannulation success rate was 63% (95% CI 53–72%), whereas the overall success rate for all 119 attempts was 53% (95% CI 44–62%, Figure 2). Of the 63 successful cannulations, 52 (83%) were successful on the first attempt. No patient had more than three cannulation attempts.

The basilic vein had a better cannulation success rate than the brachial vein (Figure 2). Cannulation attempts of the basilic vein were successful in 39 of 56 attempts (70%; 95% CI 56–81%). In 21 patients, the brachial vein was the only vein visible sonographically, and only 7 (33%) of these patients had a successful cannulation attempt.

![Figure 2. Cannulation success rates.](image-url)
There was no difference in cannulation success rate when examining the reason for difficult venous access. The success rates for IVDA, obesity, and multiple prior medical procedures groups were 62% (24 of 39; 95% CI 45–75%), 62% (5 of 8; 95% CI 25–92%), and 64% (23 of 36; 95% CI 46–79%, respectively). In patients with two or more reasons for difficult venous access, the success rate was 52% (9 of 17; 95% CI 28–77%).

The cannulation success rate for the one-person technique was 66% (50 of 76; 95% CI 54–76%), and for the two-person technique was 72% (13 of 18; 95% CI 47–90%).

The success rate in obtaining venous blood, whether or not cannulation was successful, was 79% for all patients (79/100) and for all attempts (95/119).

There were 18 nurses who enrolled patients in the study, of a total of 24 nurses who took the training. The number of patients in whom cannulation was attempted by each nurse ranged from 1–28, with a median of 3. Four nurses accounted for 52 of the 100 patient attempts. The cannulation success rate of the four top enrollers compared to the other 14 nurses was 67% (35 of 52; 95% CI 53–80%) vs. 58% (28 of 48; 95% CI 43–72%, respectively). When comparing the first half attempts of the top four enrollers to their second half attempts, the cannulation success rate was 60% (15 of 25; 95% CI 39–79%) versus 74% (20 of 27; 95% CI 54–89%, respectively). In the other 14 nurses, the first-half cannulation success rate was 67% (16 of 24, 95% CI 45–84%) vs. 50% (12 of 24, 95% CI 29–71%) in the second half.

Charts were reviewed in the 37 patients in whom ultrasound-guided cannulation was unsuccessful to assess if other cannulation was performed. In 9 patients, a peripheral line was successfully placed after more attempts, 12 patients had no further cannulation attempts, 11 patients had central venous cannulation, and five charts gave incomplete information as to further cannulation attempts.

Arterial puncture occurred in 5 patients, with four punctures occurring during brachial vein cannulation attempts and one during a basilic vein attempt. Arm numbness occurred in 3 patients, with one each during brachial, basilic, and cephalic vein cannulation attempts. Severe pain was described in 8 patients, with four occurring during brachial vein, three during basilic vein, and one during a cephalic vein cannulation attempt. All complications resolved during the ED stay.

Limitations

There are several limitations to our study. Because this was not a randomized study, it is difficult to compare success rates between veins. Nurses were free to choose which vein to cannulate, which introduced selection bias. It is possible that if we had randomized which vein should be attempted in each patient, our results might have been different. However, our study demonstrates a reasonably good success rate in a population with difficult access. We allowed the nurse to choose a vein that was well visualized, and that the nurse felt comfortable cannulating. We believe that this was the most realistic application of this technique. Also, the sample sizes for certain subgroups were small, yielding large confidence intervals around the calculated success rates.

The data form did not include information such as the vein size or depth, which might be a good marker for success rates. In addition, we did not record whether nurses used a standard 1.25-inch or a longer 1.88-inch angiocatheter. Use of the smaller angiocatheter may have resulted in a smaller amount of the catheter indwelling in the vein, leading to easier dislodgement and cannulation failure.

Nurses who participated in the study did so on a volunteer basis, and as such, might have been more motivated than others. This effect might have increased our success rates. In addition, the fact that four of the nurses performed over half of the cannulation attempts raises some important issues. First, a small group of highly motivated and skilled nurses might have artificially inflated the success rate, making the results less applicable to other settings. In response, we find no significant difference in the success rates of the top enrollers vs. the rest of the group. Also, one could raise the concern that nurses who use the technique frequently may retain and improve their skills, whereas infrequent users might show decay in skills, with decreasing success rates. Although it wasn’t statistically significant, there was an increasing success rate in the top enrollers and a decreasing rate in the rest of the group when comparing the first and second halves of the study period.

DISCUSSION

Our overall patient success rate was lower than the 87% success rate in emergency nurse-performed and 91–92% success rates in emergency physician-performed cannulation cited in earlier articles (1–3). One reason may be experience with the procedure. In one physician-performed study, five physicians performed 101 procedures, whereas we had 20 nurses performing 100 procedures (2). However, when we examined the data of our top four enrolling nurses to determine whether they improved with more experience, there was only a modest improvement from the first to the second half of the study. Another reason for the lower success rate in our study may be that we required two failed attempts and no
other visible potential sites for cannulation. By design, we selected the “worst of the worst” in terms of difficult venous access patients. Also, in the other emergency nurse-performed study, 321 patients were enrolled in 5 months, compared to 100 patients in 13 months in our study, suggesting a higher threshold of difficulty for enrollment in our patient group (1).

This study demonstrated differences in upper arm vein characteristics. The basilic vein was the most common vein for initial cannulation attempt, and had the best cannulation success rate. Interestingly, we found that the median basilic (antecubital) vein, which turns into the basilic vein in the more proximal arm, was sonographically visible in only 17% of patients, whereas the basilic vein was seen in 74% of patients. This was due to collateral veins coursing around the medial part of the upper arm that would reconstitute the basilic vein despite a sclerotic median basilic vein. The brachial vein is sonographically visible in almost all patients. Despite this, it was used as the vein for an initial cannulation attempt in 34% of patients compared to 52% for the less-commonly visible basilic vein. In addition, the brachial vein also had a lower cannulation success rate compared to the basilic vein. These results may be due to the brachial vein being often smaller and located deeper than the basilic vein. When the brachial vein was the only vein sonographically visible, it had an even worse cannulation success rate (33%). With its close proximity to the brachial artery and nerve, it also had a higher rate of artery puncture and description of severe pain during procedure. The median antecubital and cephalic veins were rarely sonographically visualized or used as first attempt, and made up only 5 of the 63 patient successes.

Cannulation success rate was not affected either by the reason for difficult venous access or the one- vs. two-person technique. It is noteworthy that the one-person technique had an equivalent success rate to the two-person technique, because needing an extra person to perform the procedure can significantly strain resources in a busy ED, and would limit its clinical benefit.

Although most nurses who received the training proceeded to use the technique during the study period, most used it only a few times, whereas a small group used it frequently. This may be due to different factors. Because not all the nurses took the training, the non-trained nurses who had a patient with difficult access would often have one of the trained nurses perform an US-guided cannulation on the patient. Thus, nurses on shifts with more non-trained nurses would have more opportunities for cannulation attempts. Also, because the difficult access patients were defined as “two previous attempts and no other visible vein to use for further attempts,” this selected for a smaller subset of the worst access patients, making for a smaller available pool of enrollees. Thus, the nurses who may have needed to wait months in between finding a patient meeting entry criteria, may have felt uncomfortable remembering the procedure, and more likely to not do the US-guided cannulation. Possible solutions to these problems would be to train all nurses in the procedure, and to do occasional refreshers to maintain procedure knowledge.

This study demonstrated that US-guidance was very good at getting a “flash,” with 79% of all attempts successful in obtaining venous blood. However, only 53% of overall attempts had a successful cannulation. Future research may then focus on examining methods that improve cannulation, such as wire-guided kits or specialized catheters.

In conclusion, although our cannulation success rate of 63% is lower than previous studies, it still demonstrates clinical benefit in that 69% of these patients had required previous central venous access. The basilic vein had the best success rate, and is likely the best first choice for cannulation, whereas it is rarely worthwhile to examine for the presence of the cephalic or median antecubital vein for cannulation. The one-person technique had a success rate equal to that of the two-person technique.

REFERENCES