Effect of Ultrasound-Guided Placement of Difficult-to-Place Peripheral Venous Catheters: A Prospective Study of a Training Program for Nurse Anesthetists

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Patients with difficult intravenous access (DIVA) often experience discomfort because of failed attempts to place peripheral venous catheters (PVCs); however, ultrasound guidance may improve this problem with catheter placement. The aim of this study was to evaluate the use of ultrasound when operated by nurse anesthetists for these patients. This prospective observational study with a pre/post design focused on inpatients with DIVA referred for PVC placement, a service provided by nurse anesthetists in most Scandinavian hospitals. The rate of success, procedure time, number of skin punctures, discomfort, catheter size, location, and incidence of central venous catheter placement are reported before and after implementation of a training program and a mobile service using ultrasound to place difficult-to-place PVCs.

The success rate increased from 0% (0 of 33 patients) to 83% (58 of 70 patients) with ultrasound. Procedure time was reduced from 20 to 10 minutes, discomfort was unchanged, and the median number of skin punctures decreased from 3 to 2. The incidence of central venous catheter placement dropped from 34% to 7%. Implementation of a training program and a mobile service in which nurse anesthetists performed ultrasound-guided PVC placement improved the success rate and quality of care in patients with DIVA.

Keywords: Catheter, central venous catheter, peripheral venous catheter, ultrasound-guided placement.

Point-of-care use of ultrasound (US) is increasingly used in healthcare, where it has proven advantages. Ultrasound-guided placement of central venous catheter (CVC) is recommended in guidelines, because of a reduction in the rate of complications. A number of publications report advantages when using US for placing peripheral venous catheters (PVCs) in patients with difficult intravenous access (DIVA). These may be patients with a history of intravenous (IV) needle abuse, steroid treatment, edema; they could be overweight or hypovolemic, and they include children. Patients with DIVA are at risk of delays regarding important intravenous (IV) treatment, and some may need CVC placement. They experience discomfort and anxiety because of the difficulty of IV access and collection of blood samples; moreover, healthcare resources may be challenged since PVC cannot be established at first attempt.

Most studies of US-guided PVC placement were carried out in the emergency department (ED) environment and were driven by ED technicians or nurses. No studies were found that addressed the use of US by nurse anesthetists to place difficult PVCs as a mobile service on wards encompassing all inpatients. Aponte et al11 investigated whether nurse anesthetists could improve the quality of care when using US-guided PVC placement in patients with DIVA scheduled for elective surgery, but found no effect compared with conventional placement. Overall rates of success are reported from 60% to 97%, with a tendency for recent studies to report higher rates. This may be a time effect due to improved US technology and improved training programs over the last 10 years. Rates of CVC placement may be reduced when US is used for PVC placement in patients with DIVA. A relative reduction of 50% to 85% is reported3,12,13; however, definitions of patients with DIVA vary, endpoints are not identical, and studies are mostly observational. Because complications associated with CVCs can lead to increased mortality and morbidity and higher costs, reducing rates of CVC placement may have a significant positive impact. Furthermore, patient-related quality of care may be improved by US-guided PVC placement. A relative reduction in procedure time of 50% to 75%1,6 has been obtained by some investigators, whereas
In the second period, we focused on patients with DIVA until we had identified more than 30 patients with DIVA. The sample size in the first phase was not fixed because the incidence of DIVA was unknown. We aimed to register consecutive patients and to record relevant procedure-related variables. A practical demonstration of the US equipment and hands-on exercises in locating specific veins (cephalic, brachial, basilic, and cubital) performed on each other. The last experience ranged from 2 through 25 years.

In our institution, as in most Scandinavian hospitals, nurse anesthetists provide a 24-hour mobile service for placing PVCs in patients with DIVA. They have extensive experience with placing PVCs because each day they handle numerous patients scheduled for surgery. When nurses and doctors at wards (including the ED) fail in placing PVCs, they request assistance by calling a dedicated pager. Nurse anesthetists then attend the patient at the ward. Because nurse anesthetists are an important part of the activities in the operating room (OR) sector and the emergency functions of the hospital, resources may be challenged, especially during night hours. In case of failure to place a PVC by the mobile nurse anesthetists and when there is an urgent need for IV treatment, the patient is taken to the OR sector, where anesthesiologists will place a CVC. This can be a stressful experience for patients, and staffing capacity can be put under pressure.

We were interested in optimizing the quality of care at “first contact” when attending patients at wards, and therefore launched a training program in mobile use of US for PVC placement. Data were collected before and after the period of implementation.

The aim of the present study was to evaluate the quality of care at first contact with inpatients with DIVA, before and after implementation of US-guided PVC placement by nurse anesthetists.

Methods

The effect of implementation of a nurse anesthetist driven program for US-guided PVC placement for patients with DIVA is described in a nonrandomized study with a pre/post design. Current practice associated with conventional PVC placement was recorded over a 3-month period to determine the incidence of DIVA and to record relevant procedure-related variables. A training and implementation period of 6 months then followed and then a second registration period of 4 months. The study population represented all inpatients and outpatients at the University Hospital of Herlev in Herlev, Denmark, for whom nurse anesthetists were requested for placement of PVC. The sample size in the first phase was not fixed because the incidence of DIVA was unknown. We aimed to register consecutive patients until we had identified more than 30 patients with DIVA. In the second period, we focused on patients with DIVA and kept the study running aiming for more than 70 patients. The primary outcome variable was the rate of success, defined as the number of PVCs placed divided by the number of patients with DIVA (given as percentage). Secondary variables were procedure time, number of placement attempts, patient-reported discomfort, and need for CVC placement. PVC size and location are also reported. Patients with DIVA were defined as patients requiring PVC insertion, where attempts by staff at wards (nurses and doctors) and nurse anesthetists using standard methods of PVC placement (no US in use) had failed. A flow diagram of patients is shown in Figure 1.

The hospital is a large urban unit with 770 beds and an annual census of 80,200 inpatients treated and 26,500 surgical procedures. Services include all specialties in internal medicine, an ED, trauma care, pediatrics for children older than 2 years, an obstetric service, most soft-tissue and hard-tissue surgery (except otolaryngologic, ophthalmologic, neurologic, and cardiothoracic), and cardiac care (except percutaneous coronary intervention).

The study was conducted in 2 phases, separated by a training and implementation period.

- Phase 1. In phase 1 (3 months), when US was not in use, nurse anesthetists recorded all contacts regarding PVC placement on wards. On a datasheet the nurse anesthetist recorded the following data: patient’s social security number (including date of birth), procedure time (time in minutes from tourniquet placement until the PVC was fixed), number of skin punctures (1, 2, 3, and ≥ 4), PVC size (≤ 22, 20, 18, and ≥ 16 gauge), patient discomfort (evaluated by a visual analog scale [VAS] from 1 to 10), level of difficulty (easy, medium, or difficult), and failure of PVC placement (defined as DIVA). Information on subsequent treatment of patients with DIVA (if a CVC was placed or the treatment was changed to an oral medication regimen) was retrieved from electronic clinical management systems (Opus, Opus Healthcare Solutions; and EPM) after the study had ended.

In the training and implementation period (6 months), 10 nurse anesthetists were trained in the use of US-guided PVC placement. The department employs 35 nurse anesthetists, and 19 applied to the training program. Ten applicants were chosen. The selected nurse anesthetists were 30 to 55 years of age, 9 were female, and their work experience ranged from 2 through 25 years.

The training program included a 1-hour lecture covering the following topics: basic US physics, anatomy of the vessels of the arm, techniques for US-guided PVC placement (in plane/long axis, out of plane/short axis), and complications. The second hour of training contained a practical demonstration of the US equipment and hands-on exercises in locating specific veins (cephalic, brachial, basilic, and cubital) performed on each other. The last hour was spent practicing US-guided PVC placement on gelatin phantoms.
After the basic skills had been acquired, 3 supervised PVC placements using US were performed on patients who were under general anesthesia and scheduled for elective surgery. Each nurse anesthetist then used a maximum period of 3 months to become routine and finally passed a test encompassing 12 questions and 1 supervised US-guided PVC procedure.

**Phase 2.** In phase 2, all patients with DIVA were referred to one of the nurse anesthetists trained in US-guided PVC placement. The variables recorded were similar to the variables recorded in the first phase; in addition, vein depth (≤0.5 cm, ≤1.0 cm, ≤1.5 cm, ≤2.0 cm, and >2.0 cm) and location were recorded. The data sheet contained an anatomical drawing of the veins, where the basilica, brachial, antecubital, cephalic, and saphena magna veins could be checked off. When PVC placement failed despite use of US, information on subsequent treatment (whether a CVC was placed or the treatment was changed to an oral medication regimen) was retrieved from electronic clinical management systems after the end of the study period. Patients were prospectively entered and registered on paper data sheets, identified by social security number. Data were then anonymously entered into spreadsheets (Microsoft Excel, Microsoft Corp) for processing and presentation of results.

The project was evaluated and approved by the Danish Data Protection Agency (Journal No. 2007-58-0015). Applicable regulations for handling of sensitive personal data and patient rights were respected. The study protocol was submitted to the Committees on Biomedical Research Ethics for the Capital Region in Denmark, whose members decided that informed consent was not needed. Nevertheless, all patients gave personal consent to placement of a PVC. Statistical calculations were performed with GraphPad Prism (version 9, GraphPad Software). Descriptive statistics were performed using nonparametric tests. Group comparisons were performed using the Mann-Whitney or χ² test. A p value ≤0.05 was considered significant.

A PVC size of 18 gauge and a length of 4.5 cm were recommended as the primary choice for US-guided PVC placement in adults with DIVA. In children, the attending nurse anesthetist chose the PVC size. We used a compact portable ultrasound device, NanoMaxx (SonoSite), with a linear probe 5 to 15 MHz. A single operator placed the PVC, the skin was disinfected with...
dedicated disinfectant swabs, a tourniquet was placed on the upper arm, and conventional US gel was used. If possible, PVCs were placed with an in-plane view; drawing blood and flushing with saline verified correct placement. The US equipment was disinfected according to the manufacturer’s recommendations between procedures. The study was initiated and conducted by the Department of Anesthesiology at the University Hospital of Herlev, which also covered all expenses, including the purchase of US equipment.

**Results**

When nurse anesthetists began using US to place difficult PVCs, the success rate rose from 0% to 83%. Procedure time was reduced by 50%, with a reduction in the number of attempts and a larger-bore PVC placed (Figure 2). Tables 1 and 2 list procedure-related variables for patients with and without DIVA, respectively.

In phase 1 (3 months), nurse anesthetists registered 315 patients, where wards had requested PVC placement because IV medication or fluids were indicated and attempts to establish IV access had failed. In this period, US-guided PVC placement was not in use. During this time PVCs were placed in 282 patients (90%, no-DIVA). In 33 patients PVC placement failed (10%, phase 1 DIVA), resulting in a success rate of 0% in these patients per definition. A CVC was placed in 11 of the 33 patients (Figure 1A).

In phase 2, only patients with DIVA were registered, and 70 patients fulfilled the criteria (failure of conventional PVC placement by nurse anesthetists). In this phase US-guided PVC placement was in use and was successful in 58 of the 70 patients, resulting in a success rate of 83%. A CVC was placed in 5 of the 70 patients (Figure 1B). The total number of patients attended by nurse anesthetists for PVC placement in the second period was not systematically registered. A data extraction from the departmental electronic activity log showed that there had been a total number of 800 requests for PVC placement by nurse anesthetists. There were no adverse events or effects reported (including arterial puncture, involvement of nerves, large hematomas, or initial misplacement of the PVC).

**Discussion**

The potential improvement in quality of care for patients with DIVA, before and after implementation of US-guided PVC placement by nurse anesthetists, was investigated in this study. A high rate of success in PVC placement was demonstrated. This success rate was achieved without increased time consumption or patient discomfort. Moreover, larger-bore PVCs could be placed with US guidance. A decreased frequency of CVC placement in patients with DIVA was found; however, this was a secondary finding.

Only one published study focusing on nurse anesthetists as operators of US-guided PVC placement was found, reporting no effect of US. However, the patients were scheduled for elective surgery, and DIVA was defined by suspicion of or a history of previous DIVA. Our patients were sampled from a much larger population (all inpatients and outpatients), and they were categorized as having DIVA only if nurse anesthetists had actually failed in placing a PVC. These patients may represent the more difficult cases, for whom using US possibly makes a significant difference.

The present study had several limitations. It was not randomized but followed a pre/post design; it therefore carries a risk of bias where uneven distribution of confounders may have had a significant impact. Registration may not be complete; if patients with DIVA were not entered, the baseline incidence of DIVA as well as probably the procedure time and number of attempts could be underestimated. Missing patients with DIVA in the second phase could render the estimate of the rate of success falsely high or low, depending on the outcome of the single patient (PVC placed or failed). The DIVA groups in the 2 periods are not the same size (33 and 70 patients, respectively). This difference is because the incidence of DIVA in our institution was not known before this study, and we used the first period to determine it. To adequately describe the development in the treatment
of the patients for whom not even US facilitated placement of a PVC, the registration of patients with DIVA in the second period continued until more than 70 patients had been entered.

The classification of a patient as having DIVA was not standardized or graded according to severity, and this may be a cause of bias. Our population consisted of patients in whom even skilled nurse anesthetists could not place PVCs and may therefore represent a sample of patients with DIVA where using US makes a significant difference. The risk of general bias in our study may be opposed by the pragmatic design without exclusion criteria. The observed results reflect the performance of a mobile service where nurse anesthetists are using US-guided PVC placement for patients with DIVA in a large university hospital. Most previous publications have focused on the population of ED or pediatric patients, where operators have been ED technicians, ED nurses, and/or emergency medicine physicians. The study by Aponte et al.11 focused on nurse anesthetists using US for PVC placement, and this population consisted of OR patients scheduled for surgery. They found no effect when US was used, and this may be explained by the differences in the study populations. In the study by Aponte et al., patients were categorized as having DIVA if they had a history of previous DIVA or physical signs indicating potential DIVA. The present study encompasses a much larger population: all inpatients and outpatients in the study periods. Moreover, the patients in our study were categorized as having DIVA only after skilled operators had failed to place PVC. These patients may not be numerous, but they do indeed challenge resources, as they would previously have been regarded as not being able to receive the intended IV treatment without a CVC. After training of nurse anesthetists in using US, a success rate for PVC placement of 83% was achieved, thus saving time and resources and minimizing patient discomfort.

Our primary endpoint, the rate of success, depends on patient-related factors as well as on operator skills

Table 2. Peripheral Venous Catheter (PVC) Procedure-Related Data From Patients Without Difficult Intravenous Access (DIVA) in Phase 1 Before Ultrasound Was in Use

<table>
<thead>
<tr>
<th>Variable</th>
<th>Phase 1 Non-DIVA (n = 282)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time used, minutes, median (IQR)</td>
<td>10 (5-15)</td>
</tr>
<tr>
<td>No. of attempts</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>189 (67)</td>
</tr>
<tr>
<td>2</td>
<td>65 (23)</td>
</tr>
<tr>
<td>3</td>
<td>26 (9)</td>
</tr>
<tr>
<td>≥ 4</td>
<td>2 (0.7)</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>1 (1-2)</td>
</tr>
<tr>
<td>PVC size, gauge</td>
<td></td>
</tr>
<tr>
<td>≤ 22</td>
<td>113 (40)</td>
</tr>
<tr>
<td>20</td>
<td>128 (45)</td>
</tr>
<tr>
<td>18</td>
<td>41 (15)</td>
</tr>
<tr>
<td>≤ 16</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Patient discomfort on VAS, median (IQR)</td>
<td>3 (2-5)</td>
</tr>
</tbody>
</table>

Table 1. Procedure-Related Variables Before (Phase 1) and After (Phase 2) Implementation of a Nurse Anesthetist–Driven Program for Ultrasound (US)-Guided Placement of Peripheral Venous Catheter (PVC) in Patients With Difficult Intravenous Access (DIVA)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Phase 1 DIVA (n = 33)</th>
<th>Phase 2 DIVA (n = 70)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of success, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVC placed</td>
<td>0 (0)</td>
<td>58 (83)</td>
</tr>
<tr>
<td>PVC failed</td>
<td>33 (100)</td>
<td>12 (17)</td>
</tr>
<tr>
<td>Time used, minutes, median (IQR)</td>
<td>20 (10-30)</td>
<td>10 (5-20)</td>
</tr>
<tr>
<td>No. of attempts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2 (6)</td>
<td>32 (46)</td>
</tr>
<tr>
<td>2</td>
<td>8 (24)</td>
<td>26 (37)</td>
</tr>
<tr>
<td>3</td>
<td>13 (39)</td>
<td>8 (11)</td>
</tr>
<tr>
<td>≥ 4</td>
<td>10 (31)</td>
<td>4 (6)</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>3 (2-4)</td>
<td>2 (1-2)</td>
</tr>
<tr>
<td>PVC size, gauge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 22</td>
<td>11 (33)</td>
<td>6 (9)</td>
</tr>
<tr>
<td>20</td>
<td>20 (61)</td>
<td>4 (6)</td>
</tr>
<tr>
<td>18</td>
<td>2 (6)</td>
<td>60 (85)</td>
</tr>
<tr>
<td>≤ 16</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Patient discomfort on VAS, median (IQR)</td>
<td>5 (3-8)</td>
<td>5 (2-5)</td>
</tr>
</tbody>
</table>

Abbreviations: IQR, interquartile range; VAS, visual analog scale.

P < .05 (phase 1 vs phase 2, Mann-Whitney test).

Abbreviations: IQR, interquartile range; VAS, visual analog scale.

aThe first column contains PVC procedure-related data from 33 patients (10% of total population) with DIVA in phase 1, when US was not in use. In these patients, even nurse anesthetists failed to place PVC. The second column contains data from 70 patients with DIVA in phase 2, when US was in use. Data are given as number (%) unless indicated by median (IQR).

bP < .05 (phase 1 vs phase 2, Mann-Whitney test).
and the quality of training.\textsuperscript{5} We applied a 3-hour tutorial session, focused practical training on a phantom, 3 supervised US-guided PVC placements in clinical context, and finally a practical and theoretical test. The quality of the educational program is regarded as satisfactory, as assessed by the rate of success and absence of adverse events. Some operators may have contributed more than others to the result, but we were not able to quantify this because registration was anonymous.

For patients, a relevant outcome may not be rate of success, because this is not synonymous with satisfactory PVC durability facilitation. PVC durability was not recorded in the present study, but others have reported median “survival” time of 26 hours and a “survival” rate of 56\% of PVCs at 96 hours.\textsuperscript{10} However, they reported that only a small proportion of patients needed a replacement PVC after 24 hours, probably reflecting general clinical improvement. Factors associated with PVC dissection PVC after 24 hours, probably reflecting general clinical improvement. Factors associated with PVC dislocation and failure is vein depth greater than 1.2 to 1.5 cm, vein diameter less than 0.4 cm, and proximal location on the arm.\textsuperscript{7-19} Five patients (7\%) from phase 2 in the present study had a PVC placed in a vein located 1.6 to 2 cm deep, and durability may therefore be reduced. A standard PVC length of 4.5 cm was used, but longer types (6 cm) are available. A randomized controlled trial from 2012 found that longer catheters (where the Seldinger technique is used for placement) will fail less often (14\% vs 45\%), but take longer time to place (17 vs 9.5 minutes), yet the rate of success is similar.\textsuperscript{20} It seems reasonable to assume that most standard 4.5-cm PVCs used will last sufficient time to meet treatment requirements in non-critically ill patients.

Procedure time in our study was reduced by 50\% (from a median of 20 to 10 minutes) with a concomitant reduction in the number of attempts and larger-bore PVC were placed (Figure 2). These findings indicate that US-guided PVC placement does not increase workload, and results can possibly be even more favorable with increasing US experience of nurse anesthetists. Moreover, the time used on patients with DIVA in the first phase did not result in any successful PVC placements, whereas the time used in the second phase did in 83\% of cases.

A systematic review and meta-analysis from 2013 including 289 patients with DIVA found that US-guided PVC placement increased the likelihood of success, but neither decreased nor increased the time used, nor changed the number of skin punctures.\textsuperscript{15} This discrepancy may be explained by several factors. Importantly, populations are probably heterogeneous because of inconsistent definition of the term DIVA. The registration of procedure time used for PVC placement in our study may not be accurate. The variable was well defined, but first, individual operators registered the time, and second the time may have been estimated instead of recorded. Moreover, when one looks at the procedure times reported in different studies, there is a large variation and a tendency toward shorter procedure time in newer publications.

When we assessed patient-reported discomfort, there was no difference whether US was used or not. Some studies report no difference in patient discomfort,\textsuperscript{9} whereas others report reduced discomfort when US is used,\textsuperscript{2} probably reflecting that the degree of discomfort is mainly determined by operator skills. Ultrasound itself is not harmful to the patient. The technique is operator dependent, and accidental arterial insertion of a PVC and the possibility of nerve damage can occur. However, there are no adverse events or effects recorded in the study period when US was in use (phase 2), and the same complications can be seen without the use of US. In the educational program, emphasis on the close relationship of the brachial artery to the brachial vein was made; hence, PVC placement in the brachial vein was not recommended as the primary choice. In only 14\% of cases, this vein was used for PVC placement. The basilic vein is not localized near the artery, and it has a large diameter; it was therefore recommended as the primary choice for catheter placement and was used in 36\% of cases. Other studies have reported complication rates of 1\% to 4\%, mostly arterial punctures.\textsuperscript{3,5}

Our rate of success for US-guided PVC placement in patients with DIVA was 83\%. As a secondary finding, we observed a reduction in the frequency of subsequent CVC placement in these patients from 34\% to 7\% (see Figure 1). However, not all patients in whom PVC placement fails need a CVC. Our results, and those of other studies, show that clinical reevaluation refers only 30\% to 40\% of patients with DIVA to CVC placement. Most of these patients are not critically ill, and US may facilitate PVC placement in up to 4 of 5 patients in this group.\textsuperscript{12} Critically ill patients will often require CVCs for management in the intensive care unit, regardless of whether a PVC can be placed or not,\textsuperscript{13} and will therefore be poor indicators of the effect of US for PVC placement. We demonstrated a reduction in the CVC placement rate from 33 to 7\%, indicating a beneficial effect of US. However, since our design is not controlled and this variable is not a primary endpoint, we cannot exclude that this finding is due to random variation or selection bias.

**Conclusion**

When nurse anesthetists were trained in using US for PVC placement in patients with DIVA, a success rate of 83\% was achieved, compared with 0\% when US was not in use. The procedure time and the number of attempts were reduced. The frequency of subsequent CVC placement decreased from 34\% to 7\%. No adverse events or effects were recorded. In conclusion, the practice was found to be safe, mobile, and efficient, and it did not seem to lead to increased use of healthcare resources or patient discomfort.
REFERENCES


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DISCLOSURES

The authors have declared they have no financial relationships with any commercial interest related to the content of this activity. The authors did not discuss off-label use within the article.