VeinViewer-assisted Intravenous Catheter Placement in a Pediatric Emergency Department

Laura L. Chapman, MD, Brenna Sullivan, MD, Amanda L. Pacheco, Charlene P. Draleau, RN, MSN, and Bruce M. Becker, MD, MPH

Abstract

Objectives: Peripheral intravenous catheter (PIV) placement is a common, painful, and frequently difficult procedure in children. The VeinViewer is a device that delineates subcutaneous veins using near-infrared light and video technology. To the best of our knowledge, the benefit of this device for PIV placement in children in the emergency department (ED) has not been studied.

Methods: The authors enrolled a prospective, randomized sample of children aged 0 to 17 years who required a nonemergent PIV in a tertiary care pediatric ED. Participants were randomized to standard PIV cannulation (SC) or PIV cannulation with the VeinViewer (VV). The primary outcome measure was time to PIV placement. Secondary outcome measures included number of PIV attempts and pain scores as reported by the child, parent or guardian, and nurse using a 100-mm visual analog scale (VAS).

Results: A total of 323 patients completed the study: 174 boys and 149 girls. Age, sex, and body mass index (BMI) were not different between groups. There were no differences in time to PIV placement, number of PIV attempts, or pain scores for the overall study group. However, a planned subgroup analysis of children age 0 to 2 years (n = 107) did yield significant results for the geometric mean time to place the PIV (121 seconds [VV] vs. 167 seconds [SC], p = 0.047) and for nurses’ perception of pain (median VAS 34 [VV] vs. 46 [SC], p = 0.01).

Conclusions: While no results were significant for the overall study group, subgroup analysis of children age 0 to 2 years suggests that the VeinViewer may decrease the time to PIV placement.

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nsertion of intravenous (IV) catheters is a common procedure in the pediatric emergency department (ED) and is frequently a source of pain and anxiety for children. Peripheral intravenous catheters (PIVs) are generally placed using visual or tactile cues. These techniques may be inadequate in children because their veins are smaller, they have increased subcutaneous fat, and their skin is more elastic than that of adults. As a result, health care workers often struggle to place PIVs in children. As reported in recent literature, the average number of punctures required to achieve successful catheter placement in children is 2.35, with a range of 1 to 10. Multiple attempts at PIV placement can lead to delays in treatment, increased use of human resources, and patient and parent distress.

Peripheral IVs are one of the leading causes of pain in hospitalized children, and venipuncture by nurses is commonly seen as one of the most painful invasive procedures performed in children. Children recording visual analog scale (VAS) pain scores in response to

From the Department of Pediatric Emergency Medicine (LLC, CPD, BMB), Hasbro Children’s Hospital; the Brown Alpert Medical School (LLC, BS, BMB); and the Department of Emergency Medicine (BMB), Rhode Island Hospital (ALP), Providence, RI. Received December 1, 2010; revisions received February 14, March 17, and March 21, 2011; accepted March 23, 2011. Presented at the Society for Academic Emergency Medicine (SAEM) annual meeting, New Orleans, LA, May 14–17, 2009; the SAEM annual meeting, Washington, DC, May 29–June 1, 2008; and the Pediatric Academic Societies’ annual meeting, Baltimore, MD, May 2–5, 2009.

Funding sources/disclosures: Christie Medical (formerly Luminetx) provided the VeinViewer device (Model VV1.0) and funding for the independent statistical analysis. No additional funding was provided, and Christie Medical had no further role in the study.

ClinicalTrials.gov number NCT00468065.

Supervising Editor: James Miner, MD.

Address for correspondence and reprints: Laura L. Chapman, MD; e-mail: chapml@gmail.com
PIV catheter placement in the ED have rated the pain as 3.23 to 5.0, and their parents have rated their children’s pain as 3.4 to 5.0. Distraction techniques have been shown to significantly decrease pain perception.

In this study, we tested the VeinViewer by Christie Medical (Cypress, CA) as an adjunctive aid in the placement of peripheral PIVs in children. The VeinViewer is a hands-free, noninvasive device that projects near-infrared light onto a patient’s skin. A digital video camera captures the light reflected back that surrounds the veins, while no light is reflected from the veins. A microprocessor adds contrast, and then a real-time image of the vessels is projected on the patient’s skin. In a prior study, the VeinViewer was shown to delineate veins not otherwise visible with the naked eye.

Hess, at Wolfson’s Children’s Hospital, used the VeinViewer to perform IV cannulations in a pediatric inpatient population and reported a 31% increase in first IV attempt success rate with a decrease in mean number of sticks from 1.97 to 1.29 (a 35% decrease), and a decrease in time required for successful IV cannulation in 39% of patients receiving their cannulation from an operator using the VeinViewer, when compared to standard care. To the best of our knowledge, use of the VeinViewer for PIV placement in children in the ED has not been studied. We hypothesized that the VeinViewer, when used for PIV placement in a pediatric ED, would lead to decreased time to PIV placement, decreased number of PIV attempts, and decreased pain scores.

METHODS

Study Design

We conducted a prospective randomized controlled clinical study of children treated in a pediatric ED who required PIV placement as part of their routine care. The hospital institutional review board approved this study. Informed consent was obtained from all parents or guardians, and assent was obtained from all children 8 years of age and older.

Study Setting and Population

A convenience sample of children age 0 to 17 years of age was enrolled from April 2007 to September 2008 in an urban tertiary pediatric ED with 45,000 visits annually. Exclusion criteria included non–English-speaking patients or parents/guardians and need for an emergent PIV as determined by the treating provider. Participants were recruited when trained research assistants were available during afternoon and evening hours 6 to 7 days a week.

Study Protocol

Patients were randomized to receive either PIV placement using standard technique or to receive PIV placement with the aid of the VeinViewer. Randomization was performed using a computerized random number generator. Pediatric emergency nurses placed all PIVs. Prior to the initiation of the study, all nurses and research assistants attended one of four 30-minute standardized training sessions conducted by the primary investigator. These sessions covered an overview of the study, VeinViewer operation, and hands-on use of the VeinViewer with one to two PIV placements on a healthy adult volunteer. A technical representative from Christie Medical was available at each training session to answer questions about the device.

Outcome Measures

Research assistants collected data on patient demographics, body mass index (BMI), and skin color. Skin color was categorized by the parent or patient using a scale of 1 (light) to 6 (dark). Use of topical lidocaine (LMX4, Ferndale Pharmaceuticals Ltd., Leeds, UK) prior to the IV attempt was recorded. Its use was left to the discretion of the treating nurse, and was placed prior to study enrollment.

The research assistant recorded time to successful PIV placement. The time started when the tourniquet was placed or when the nurse began looking for a site, whichever came first. Recorded time was stopped when successful PIV cannulation was achieved and blood was drawn or saline was flushed. The PIV was deemed unsuccessful if blood could be withdrawn but the following saline flush was unsuccessful. When multiple attempts were required, total time was recorded as the sum of individual PIV attempts. Number of attempts was also recorded.

In addition, the nurse rated the difficulty of PIV placement and the perceived helpfulness of the VeinViewer PIV placements in the intervention arm of the study. Difficulty of placement was rated on a scale of 1 to 3, with 1 rated as “easy,” 2 as “slightly difficult with some probing required,” and 3 as “very difficult.” This three-point scale was developed for and used successfully in the investigators’ previous work on decreasing the pain of IV cannulation in children using an ultrasound-driven medical device and topical anesthetic. We chose this scale because the difficulty of IV cannulation is subjective and reflects the experience and confidence of the nurse. We were interested in the relationship between PIV difficulty and the nurses’ perception of the “helpfulness” of the VeinViewer. Helpfulness of the VeinViewer was rated using a VAS ranging from 1 (not helpful) to 100 (extremely helpful).

Patients age 8 to 17 years rated the pain of PIV placement on a 100-mm VAS, ranging from 1 (no pain) to 100 (maximum pain) immediately after the PIV was placed. Patients under the age of 8 were not asked to rate their pain. Parents and nurses rated what they perceived as the child’s pain for ages 0 to 17 years using the same 100-mm VAS.

Data Analysis

Data analyses were performed by Datacorp, a private, independent, and federally certified company (Datacorp, Smithfield, RI). The primary outcome measure was time to PIV placement. With a sample size of 200 patients, the trial had a power of 80% to detect a reduction in time to PIV placement by 20% with a Type I error of 5%. The investigators chose an effect size of 20% based on preliminary research done by Hess at Wolfson’s Children’s Hospital using the VeinViewer.

Prior to analysis, time to PIV placement was found to be right-skewed, so a logarithmic transformation using
base-e was performed to reduce the skewness. Time to PIV placement was then analyzed with a two-group analysis of variance (ANOVA), which is equivalent to a two-sample t-test with equal variance assumption. Following ANOVA analyses, the geometric mean of time to PIV placement for each group and 95% confidence intervals (CI) were computed by taking the exponent (e^x) of the mean and of the lower and upper limits of the 95% CIs of the ln-transformed time.12 Thus, the times to PIV placement reported some tables are scaled in seconds, rather than ln seconds (a less clinically relevant number). The time to PIV placement is reported as a means with a p-value and 95% CI.

Baseline factors such as demographics (age, race, sex, BMI) and use of topical lidocaine were compared between the intervention and standard care groups with t-tests and chi-squared tests.

Secondary outcome measures included number of PIV attempts; VAS pain scales reported by the patient, nurse, and parents/guardians; and helpfulness of the VeinViewer on a VAS. The number of PIV attempts and the VAS pain scales were analyzed using the Mann-Whitney U-test and are reported as medians and inter-quartile ranges (IQRs). Helpfulness of the VeinViewer was only reported for patients whose PIV was placed using the VeinViewer. For analysis, helpfulness of the VeinViewer was grouped by nurse-reported level of PIV difficulty of placement: easy, slightly difficult, and very difficult. This variable was then analyzed using the Kruskall-Wallis test to compare the helpfulness of the VeinViewer for these three levels of PIV difficulty of placement. Mann-Whitney U and Kruskall Wallis results are reported as medians and IQRs. Differences between medians were calculated using the Hodges-Lehmann estimator and are reported as p-values and 95% CI.

Patient age was considered a potential moderator for our outcome variables; thus planned subgroup analyses for young children age 0 to 2 years were performed. We chose this age range because we believe that these are typically the most difficult patients to place PIVs in and, thus, may benefit more from VeinViewer assistance with PIV placement. Analyses were conducted using SPSS 18.0 (SPSS, Inc., Chicago, IL).

RESULTS

Time to PIV Placement and Number of Attempts

Between April 2007 and September 2008, a total of 336 children were enrolled: 171 patients were randomized to PIV placement with the VeinViewer, and 165 were randomized to standard care PIV placement (Figure 1). Eleven patients were withdrawn from the VeinViewer group and three from the standard care group. Reasons for withdrawal are shown in Figure 1. In all of the cases where the nurse withdrew the patient from the study, blood was successfully drawn on the first PIV attempt, but the PIV could not be flushed. In these cases, the nurses subsequently conferred with the physician who determined that PIV placement was no longer indicated. Patients in the VeinViewer group were similar in

![Figure 1. Patients enrolled and withdrawn from study. PIV = peripheral intravenous catheter; RA = research assistant.](image-url)
demographic data to those in the standard care group with no significant differences in age, sex, race, BMI, skin color, or use of topical anesthetic (Table 1).

For the entire group of children age 0–17 years, there were no differences in time to successful PIV placement or number of PIV attempts (Table 2). Successful PIV placement on the first attempt compared to two or more attempts was 79% in the VeinViewer group and 78% in the standard care group ($\chi^2(1) = 0.39, p = 0.53$).

The subgroup analysis of children age 0 to 2 years yielded significant results for time to PIV placement, with the geometric mean time of 121 seconds in the VeinViewer group and 167 seconds in the standard care group ($p = 0.047$; Table 2). Number of PIV attempts was not significantly different. Successful PIV placement on the first attempt compared to two or more attempts was 73% in the VeinViewer group and 61% in the standard care group in children age 2 and younger ($\chi^2(1) = 1.68, p = 0.19$).

Nurses’ Perceived Difficulty of PIV and Helpfulness of VeinViewer

Nurses rated 73.5% of all PIVs placed with the VeinViewer as easy, 19% as slightly difficult, and 7% as difficult. The helpfulness of the VeinViewer did not change with PIV difficulty with median VAS ratings of 49, 51, and 39 in the easy, slightly difficult, and difficult categories, respectively ($p = 0.29$; Table 3).

Pain Assessment

In children age 8–17 years, there were no differences in the median VAS scores reported by the patients, parents, or nurses. Subgroup analysis of children age 0–2 years showed no differences in pain reported by the parents, but the nurses reported less perceived pain when the VeinViewer was used (median VAS = 34 vs. 46; $p = 0.01$; Table 4). As reported in prior literature, this difference is considered clinically significant for acute pain.$^{13–15}$

**DISCUSSION**

We evaluated the VeinViewer to determine if it could aid the placement of PIVs in a pediatric ED. In the overall study group, the VeinViewer did not lead to decreased time for PIV placement or fewer PIV attempts. However, subgroup analysis demonstrated decreased time for PIV placement in children under the age of 2 years.

The majority of PIVs were placed on the first attempt: 79% in the VeinViewer group and 78% in the standard care group. This outcome was unexpected, because the literature reports an average of two to three attempts per child.$^4$ In our ED, we have nurses who are specially trained in pediatrics with many years of experience working in pediatric EDs. The experience and skill of the nurses starting PIVs for this study may have obviated the utility of the VeinViewer. In a subgroup analysis of children under the age of 2 years, the use of the VeinViewer led to decreased time to PIV placement. The clinical significance of this outcome is unclear, since the decrease in time was

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**Table 1**

Demographic Characteristics of Patients*

<table>
<thead>
<tr>
<th>Demographic Characteristics</th>
<th>VeinViewer ($n = 163$)</th>
<th>Standard Care ($n = 160$)</th>
<th>Comparison</th>
<th>Difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr), mean ± SD</td>
<td>6.8 ± 5.5</td>
<td>6.5 ± 5.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male, %</td>
<td>52</td>
<td>56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonwhite race/ethnicity, %</td>
<td>40</td>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI, mean ± SD</td>
<td>21.7 ± 7.2</td>
<td>20.5 ± 6.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topical anesthetic, %</td>
<td>76</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin 1 (light) to 6 (dark), %</td>
<td>32</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–2</td>
<td>32</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3–4</td>
<td>55</td>
<td>54</td>
<td></td>
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<tr>
<td>5–6</td>
<td>13</td>
<td>17</td>
<td></td>
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</tbody>
</table>

BMI = body mass index.

*Mean values are reported with ±SD. There were no significant between-group differences.

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**Table 2**

Results Comparing the VeinViewer and Control Groups

<table>
<thead>
<tr>
<th>Results</th>
<th>VeinViewer ($n = 163$)</th>
<th>Standard Care ($n = 160$)</th>
<th>Comparison</th>
<th>Difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ages 0–17 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geometric mean time to place PIV, seconds</td>
<td>132</td>
<td>145</td>
<td>0.40</td>
<td>1.1 (3.086–1.37)*</td>
</tr>
<tr>
<td>Median number of PIV attempts (IQR)</td>
<td>1 (1–1)</td>
<td>1 (1–1)</td>
<td>0.5</td>
<td>0 (1–1)</td>
</tr>
<tr>
<td>Ages 0–2 years only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geometric mean time to place PIV, seconds</td>
<td>121</td>
<td>167</td>
<td>0.047</td>
<td>1.39 (1.29–1.82)*</td>
</tr>
<tr>
<td>Median number of PIV attempts (IQR)</td>
<td>1 (1–2)</td>
<td>1 (1–2)</td>
<td>0.23</td>
<td>0 (1–2)</td>
</tr>
</tbody>
</table>

IQR = interquartile range; PIV = peripheral intravenous catheter.

*Difference and 95% CI are for the ratio of the geometric means; n, number of patients.

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**Table 3**

Nurses Report of Helpfulness of the VeinViewer*

<table>
<thead>
<tr>
<th>PIV Difficulty</th>
<th>Easy</th>
<th>Slightly Difficult</th>
<th>Very Difficult</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median VAS for helpfulness (IQR)</td>
<td>49 (13–65)</td>
<td>51 (34–66)</td>
<td>39 (30–59)</td>
<td>0.29</td>
</tr>
</tbody>
</table>

VAS = visual analog scale.

*Kruskall Wallis test, VAS 0 = not helpful to 100 = extremely helpful.
approximately 45 seconds. This finding is, however, suggestive that further studies in young children and infants may find the VeinViewer to be helpful with PIV placement, especially when the nurses starting these PIVs are less experienced with children (e.g., those working in the many community hospital EDs and urgent care centers where children make up less than 20% of the total census).

Time to PIV placement in our study was shorter than that reported in the literature.6,9 This is likely due to the way we recorded time to PIV placement. When multiple attempts were required, total time was recorded as the sum of individual PIV attempts. We omitted the time between attempts, such as time spent looking for additional supplies or recruiting additional nursing staff, to limit factors that could bias the study and could lead to outliers with unusually long times.

There was no difference in reported pain by the child, parent, or nurse for the entire study group. There was a significant difference in nurse reporting of the child’s pain in the 0- to 2-year-olds, although parents did not perceive this difference. There are several potential explanations for this finding: the VeinViewer acted as an effective distraction for the younger children, the shorter time to place the PIV led to decreased perceived pain by the nurse, the focus of the nurses using the VeinViewer was diverted away from the patient’s pain behaviors and toward the visual image projected by the machine, or the nonblinded nature of the study biased the raters. Furthermore, we did not determine the pain ratings for children 0 to 7 years old, other than what the nurse and parent perceived their pain to be.

Nurses found the VeinViewer to be moderately helpful with all PIV placements, regardless of PIV difficulty (Table 3). With the majority of PIV placements rated at easy and only 7.5% rated as very difficult, the sample size is not large enough to interpret helpfulness of the VeinViewer for difficult PIV placement.

LIMITATIONS

Our results were limited by the higher-than-expected rate of success of PIV placements and short time to PIV placement in the control group. All PIVs were placed by highly skilled pediatric emergency nurses. It is possible the VeinViewer would have been more helpful for nonpediatric specialty nurses or for those learning PIV placement, such as medical students, residents, and nursing students. In addition, our scale of PIV difficulty was subjective and may have led to bias about helpfulness of the VeinViewer. A more objective measure of PIV difficulty that reflects hydration status, BMI, or history of multiple PIVs with venous sclerosis would help overcome this potential bias. Our pain scoring system was also limited because we had no means to video record children under the age of 7 years to assess their pain levels.

CONCLUSIONS

Our study suggests that the VeinViewer may decrease the time to IV catheter placement in young children and infants. However, it did not demonstrate significant benefits in older children.

Table 4

<table>
<thead>
<tr>
<th>VAS Pain Scores</th>
<th>VeinViewer (n = 163)</th>
<th>Standard Care (n = 160)</th>
<th>Comparison p-value</th>
<th>Difference (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient pain age 8–17 yr, median (IQR) [n]*</td>
<td>21 (6.5 to 48) [89]</td>
<td>25 (7 to 68) [79]</td>
<td>0.37</td>
<td>4 (–3 to 10)</td>
</tr>
<tr>
<td>Parent pain age 0–17 yr, median (IQR)</td>
<td>39 (12.5 to 70.5)</td>
<td>46 (16.5 to 70)</td>
<td>0.34</td>
<td>7 (–1.0 to 8)</td>
</tr>
<tr>
<td>Nurse pain age 0–17 yr, median (IQR)</td>
<td>25 (12 to 44)</td>
<td>29 (14 to 50)</td>
<td>0.16</td>
<td>4 (–3 to 12)</td>
</tr>
<tr>
<td>Parent pain age 0–2 yr, median (IQR)</td>
<td>66 (39 to 98)</td>
<td>70 (45 to 97)</td>
<td>0.8</td>
<td>4 (–8 to 13)</td>
</tr>
<tr>
<td>Nurse pain age 0–2 yr, median (IQR)</td>
<td>34 (20 to 50)</td>
<td>46 (31 to 62)</td>
<td>0.01</td>
<td>12 (2 to 19)</td>
</tr>
</tbody>
</table>

IQR = interquartile range; VAS = visual analog scale.

*Age 8–17 only; n, number of patients.

References

8. Jacobson A. Intradermal normal saline solution, self-selected music, and insertion difficulty effects.


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