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Pediatric Peripheral Intravenous Access

Does Nursing Experience and Competence *Really* Make a Difference?

ABSTRACT

Placement of peripheral pediatric intravenous (IV) catheters in infants and children is difficult, even in skilled hands. This large, 2-institution prospective study used real-time independent observations to describe the effect of nurse experience and competence on the length of time and the number of attempts to establish a successful IV placement in the hospitalized child. Data from a convenience sample of 592 evaluable patients and 1135 venipunctures showed that successful IV placements required an average of 2 venipunctures over 28 minutes. Although nurse experience and self-rated competence were correlated with attaining a successful IV placement, time of day, predicted difficulty of the venipuncture, and cooperativeness of the child appeared to be better predictors of success.

Hospitalized children usually require vascular access for administration of fluids or medications. Even in skilled hands, placement of peripheral intravenous (IV) catheters in infants and children is a difficult task. Often IV attempts are not successful, and more than 1 attempt is necessary. As expected, placement of an IV is both painful and stressful for a child. Merely searching for an IV site may be as stressful as the needle venipuncture. When multiple IV attempts are required, the child's stress is increased, and child and parental satisfaction with care may be diminished.

In the literature, reports of objective data on the number of peripheral IV attempts or the length of time needed to obtain successful vascular access in pediatric hospitalized patients are limited. The few existing reports analyze samples that come from a single institution and are small in size or include adults along with children. In a study that included both children and adults (mean age 63 years), Jacobson and Winslow[1] looked at 339 IV attempts by 34 nurses in a

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large urban hospital. The length of time needed to start the peripheral IV was self-reported. In this predominantly adult population, the mean time to start the IV was 40 seconds (range, 2-311); 77% of the IVs were ultimately successful, 65% on the first venipuncture.

Most of the adult and pediatric IV access literature has focused on techniques to increase the likelihood of a successful IV placement[2,3] or on the reduction of pain during the procedure.[4-7] Some studies have focused on time and personnel costs, usually with the goal of supporting a special team for IV placement.[8] In a general hospital population, Costantino et al[9] found that IV nurse specialists were very successful in placing IVs, with 91% of 430 IVs placed with 1 attempt. Frey[8] surveyed registered nurses, interns, residents, and an IV nurse specialist regarding the success rate of IV attempts over a 2-week period in a pediatric hospital. Nurses self-reported 44% successful IV placement starts (86 of 197 attempts), physicians were only 23% successful (95 of 416 attempts), and the IV nurse specialist was successful 98% of the time (42 of 43 attempts).[8] Overall, only 223 of 656 IV attempts (34%) were successful on the first attempt. This study established that to obtain a successful peripheral IV, nurses with experience, such as found with an IV specialist team, are more likely to establish an IV with fewer venipunctures, less time, and less cost.[8]

In a prospective study of nurses in a children's hospital, Lininger[10] also used self-reporting to study the number of attempts necessary for a successful IV placement. It took an average of 2.35 attempts to place a pediatric IV, with only 53% of the venipunctures successful on the first attempt. Ninety-one percent were successful by the fourth attempt. Similar findings were noted by Yen et al.[3] In their study, emergency department nurses in a large urban hospital successfully placed pediatric IVs on the first try 75% of the time, and 86% (529) were eventually successful with an average of 1.4 attempts (range, 1-10).

Few studies have addressed the variables that affect the success or difficulty in placing IV catheters by *general pediatric* nurses. Jacobson and Winslow[1] found experience, age, and high confidence levels in IV placement to be significantly related to success at placing IV catheters in adult and pediatric patients. Insertion times were also shorter for nurses who had higher self-rated IV placement skills. It seems intuitive that training and experience would affect the rate of successful IV placement. A study of pediatric nurses with 5 or more years' experience noted a first-attempt success rate of 74% to 86%.[11] However, Black et al[2] found that years of nursing experience were not significantly related to IV success, and success rates were significantly lower for children weighing less than 5 kg or with previous IVs.

OBJECTIVES

The primary objective of this research study was to describe, with improved accuracy, the number of attempts and the amount of time required by general pediatric nurses to achieve successful peripheral IV catheter placement in hospitalized children. Secondary objectives reported here include the independent observation of the amount of time and number of venipunctures to successful IV placement in relationship to several nurse and patient characteristics.

Research Questions

1. What is the relationship of the pediatric nurse's experience on the amount of time and number of attempts to successful placement of peripheral IV catheters in hospitalized children?
2. What is the relationship of the pediatric nurse's competence on the amount of time and number of attempts to successful placement of peripheral IV catheters in hospitalized children?
3. How does the patient characteristic of expected difficulty of the IV placement affect the amount of time and number of attempts to successful IV placement?
4. How does the patient characteristic of uncooperativeness affect the amount of time and number of attempts to successful IV placement?
5. Does nursing shift (day or night), age, sex, race, weight, or weight percentile affect the amount of time and number of attempts necessary to obtain a successful IV placement?

METHODS

Design

The authors conducted a prospective observational study of peripheral IV insertions at 2 institutions. Both institutional review boards approved the study. Accuracy of data was obtained using independent direct observations for data collection rather than self-report.

Setting

Data were collected at 2 pediatric hospitals with hospitalist services in the southeastern United States. The hospitals are tertiary care teaching centers providing inpatient, outpatient, and intensive care services. Serving both rural and urban areas, the hospitals provide specialized care to a wide variety of patients from diverse social and economic conditions and encounter a wide variety of clinical conditions. On the inpatient units, registered nurses provide primary pediatric nursing care and are responsible for initiation and maintenance of their patients' IV catheters. Specifically, IV teams are not used. After a peripheral IV is ordered, the primary nurse attempts the placement. If 2 or 3 attempts by the primary nurse are unsuccessful, a second nurse attempts the IV. If the IV access appears particularly difficult, assistance from more experienced nurses or intensive care personnel may be requested. Child life services

were available to provide distraction and to help decrease the fear of venipuncture. Nursing assistants were in the room to help in positioning the child and to help provide comfort for the child and the family members (if they chose to be with the child during the procedure). Topical anesthetics were also used for pain management in some of the children, and ancillary devices for vein illumination were also used per nurses' discretion and preference.

Study Population

This clinical study population included 2 samples. One was a convenience sample of pediatric patients requiring peripheral IV access. All pediatric patients (newborn to 18 years of age) admitted to the general pediatric services who had written or verbal orders for insertion of an IV were eligible for the study. Patients in the newborn nursery and intensive care units (neonatal or pediatric) were excluded. Additional exclusion criteria included children on patient-controlled analgesia pumps, terminally ill children, children transferred from the operating room less than 8 hours postanesthesia, or any child the research staff deemed unobservable. Each child was assigned a unique identifier to protect confidentiality.

The second convenience sample was obtained from nurses working on the inpatient pediatric units. General venipuncture training is included in hospital orientation, and nurses receive additional specific education and training on pediatric venipuncture during unit orientation. Nurses were briefed on the study during initial educational meetings. All nurses on the units were eligible to participate. Nurses who gave informed consent to be observed during the placement of the IV indicated their work experience and their perceived level of competence to place a pediatric IV catheter. Each nurse was assigned a unique identifier to protect confidentiality.

Study Variables and Definition of Terms

The following variables and definition of terms were used for this study:

1. *Encounter*. An encounter occurred whenever a venipuncture attempt was observed and timed by an independent research staff.
2. *Attempt*. An IV attempt was defined as the skin being pierced by the needle. The number of IV attempts was totaled at the conclusion of the encounter.
3. *Successful IV placement*. In a successful IV placement, blood flowed freely from the catheter, and the catheter was able to be flushed.
4. *Time*. During an encounter, a stopwatch was started when the nurse began actively looking for an IV site. Time was recorded in seconds and rounded to the nearest whole minute. The watch was stopped when there was a successful IV placement attempt or when the decision was made to abort further attempts.
5. *Cooperative*. Research personnel presented a card with the words "cooperative" or "uncooperative" to each nurse before the attempted venipuncture. The nurse indicated if the child was expected to be cooperative or uncooperative.
6. *Difficulty*. Nurses indicated the degree of anticipated difficulty with IV placement. They were presented with a card that indicated 1 = little difficulty, 2 = somewhat difficult, and 3 = very difficult. For data analysis, this variable was collapsed to "not difficult" or "difficult."
7. *Demographics*. Chart review was used to obtain patient age, weight, race, sex, and diagnoses.
8. *Experience*. Nurse experience was self-reported. At the time of informed consent, each nurse indicated the amount of general pediatric nursing experience as less than 1 year, 1 to 3 years, 3 to 5 years, or more than 5 years. The nurse also indicated previous adult nursing experience (*yes*, *no*).
9. *Competence*. Nurses self-rated their perception of competence in successful placement of pediatric IVs. Categories of competence were based on the Dreyfus model of skill acquisition: *novice*, *advanced beginner*, *competent*, *proficient*, and *expert*.[12]

Data Collection

Data were collected between October 1, 2007, and October 31, 2008. Independent research personnel observed IV encounters directly and timed the IV attempt with a stopwatch. They were trained at 1 institution for standardization of measurement and data collection using a protocol manual. There were frequent follow-up communications to maintain consistency of data collection.

During study hours between 7:00 AM and 11:00 PM, the research personnel were present on the hospital units and identified possible patient subjects by frequent communication with the nurse managers, unit secretaries, and nurses. If more than 1 IV was being placed at the same time in different rooms or on different units, a table of random numbers was used to determine which patient would take part in the study.

After notification of plans for IV placement, the research personnel invited the patient and family to participate in the study and obtained informed consent. If the child was able to understand the process (usually 7 or more years old), his or her assent was also obtained. It was made clear to parents or guardians that consent was not for IV placement, but to have the encounter watched by the independent observer.

Statistical Methods

Statistical analysis software (SAS 9.2 and JMP 8, Cary, North Carolina) was used for analyses. Data analysis

was divided into 3 parts:

1. Logistic regression models were used to examine what factors influence the chance of a successful IV placement with the *first* attempt.
2. Repeated-measures logistic regression models were used to look at covariates that significantly affected the chance of *overall* successful IV placements.
3. Proportional hazard models were used to examine the first and second nurses' time to successful IV placement. Since 84% of successful IV placement was accomplished with 1 or 2 nurses, the data were stratified by first and second nurses to study factors that influenced the time to successful IV placement and to make comparisons.

Analyses were complicated by the fact that some children had a successful IV placement with 1 nurse on the first attempt, whereas others required several nurses and multiple attempts. Because of the changes in nurses and multiple IV attempts per child, most naive statistical analyses would be biased. Thus, advanced methods were used to make adjustments for some of the different IV encounters. Where appropriate, these methods controlled for nurse changes between attempts, as several different nurses may have performed multiple attempts on the same child during a single encounter. For statistical purposes, there were 2 assumptions:

1. There was likely a *within-subject* correlation because of the possibility of multiple attempts on the child during the same IV encounter.
2. There was no *between-subject* correlation. During the entire study, less than 4% of the encounters involved observing the same child a second or third time.

All statistical modeling used backward model selection and was validated with bootstrap resampling (used to estimate variability and bias) whenever possible. Significance was set at the .05 level in the original data and at least 50% of the bootstrap resampling.

RESULTS

Demographic Characteristics

The study patient population consisted of 592 patient encounters with 1135 needle venipuncture attempts. Data were collected for up to 10 needle venipuncture attempts per patient encounter; 1 encounter with 15 attempts was excluded from the analysis as an outlier. Participants were mainly white (42%) and African American (47%); 56% were male. The average age of the patients was 5.25 years, but the median age was 2 years. A diagnosis of at least 1 chronic illness (eg, sickle cell, asthma, cancer, neurologic disorder) was documented in 49% of the participants.

How Many Attempts and How Much Time?

More than 90% of encounters ultimately resulted in a successful IV placement. It took an average of 2.1 venipunctures to obtain the IV, and more than 50% of the children required 2 or more attempts. The mean time required to start the IV was 28.43 (SD = 28.06) minutes with a median of 20.0 minutes.

Did the Child's Age, Race, and Weight Affect the Number of Attempts or Time to Successful IV Placement?

Infants and children younger than 2 years took significantly longer to have successful IV placement ($P < .0001$), averaging 5 minutes more than children older than 2 years. In addition, 60% of children younger than 2 years required more than 1 attempt for successful IV placement than 45% of children older than 2 years ($P < .0003$). There was also an inverse relationship between time needed to obtain a successful IV placement and weight ($r = -0.193$, $P < .001$).

Since the vast majority (89%) of the sample consisted of white and African American children, comparisons between races were limited to these 2 groups. No significant difference was found between racial groups with respect to either the time to a successful IV placement or the chance of a first-attempt failure.

What Was the Experience Level and Perceived Competence of the Participating Nurses?

For the 2 study hospitals, 159 of 201 eligible nurses (79%) agreed to enroll in the study, and 143 were actually observed. Most unobserved nurses worked the 7:00 PM to 7:00 AM shift. One-quarter of the nurses (27%) had less than 1 year's experience. Nurses with more than 5 years' experience were the largest group (36%), whereas 24% had 1 to 3 years' experience, and 13% had 3 to 5 years' experience.

Nurses self-classified their IV placement skills as *novice*, *advanced beginner*, *competent*, *proficient*, or *expert*. Of the observed nurses, almost 30% considered themselves to be novice or advanced beginner, whereas 44% ranked themselves as proficient or expert.

What Effect Do Nursing Experience and Competence Have on Successful IV Starts?

Nurses with less than 1 year's experience performed one-third of the first IV venipunctures; 66% of these attempts were not successful. If more than 2 venipunctures were required, the more experienced nurses were recruited (Table 1). When a third or fourth venipuncture became necessary, more than 60% were done by nurses with proficient or expert skill, and only a small

TABLE 1

Level of Experience and Competence for Nurses Based on How Many Attempts Were Needed to Attain Successful IV Placement

	1st Attempt, %	2nd Attempt, %	3rd Attempt, %	4th Attempt, %
Experience, y				
<1	34	24	11	9
1-3	31	33	41	25
3-5	12	14	12	12
<5	23	29	36	54
Total	100	100	100	100
Competence				
Novice	17	12	9	8
Advanced beginner	22	14	6	3
Competent	23	28	22	16
Proficient	30	35	53	54
Expert	8	11	10	19
Total	100	100	100	100

percentage of these venipunctures was performed by novice (17%) or advanced beginner (9%) nurses. For successful IV placement attempts only, Table 1 shows that third and fourth attempts were successfully placed by nurses with more experience or who perceived themselves to be proficient or expert at IV placement.

How Many Nurses Were Required for a Successful IV Placement?

Whether by written policy or by nursing practice, there were usually no more than 2 or 3 venipunctures attempted before requesting an attempt by a different nurse. More than 60% of encounters had successful IV placement with 1 nurse, and 84% of observations were successful with 1 or 2 nurses. Ninety-one of the 592 encounters required 3 or more nurses, and in some cases, as many as 7 different nurses might have attempted the IV.

Did the Time of Day (Nursing Shift) Affect Successful IV Placements?

Of the IV encounters observed, nearly 60% of all patient observations occurred during the day shift (7:00 AM to 7:00 PM). Of the 592 first attempts, the majority (63%) of the unsuccessful venipunctures occurred during the day shift ($P < .01$). Roughly 60% of the nurses with the least confidence and years of experience worked the day shift, coinciding with the largest group of nurses that did not have a successful needle venipuncture. In this case, nursing work shift may be a surrogate for inexperience or perceptions of less competence.

What Factors Predicted a Successful IV Placement With the First Venipuncture?

Standard logistic regression was used to examine what factors influence the chance of a successful IV placement with only 1 attempt on the first try. Variables entered into the model were nurse experience and competence, demographics of the child (age, weight, race, and sex), nurse-perceived difficulty of venipuncture, day or night shift, and cooperativeness of the child. The use of topical anesthetic creams was infrequent (14%) and was not included in the analyses.

Three significant predictors of success on the first IV attempt were found: (1) the shift during which the IV was attempted; (2) the perceived difficulty of the venipuncture; and (3) the level of cooperation expected of the child. Nurse experience and nurse competence did not appear to affect success significantly for the first venipuncture (Table 2).

What Are the Chances of a Successful IV Venipuncture Among All IV Attempts?

Repeated-measures logistic regression was used to assess each nurse's IV attempt in order to determine what

TABLE 2

Parameters and Odd Ratios for Success With First Attempt

Parameter	Estimate	SE	P	Odds Ratio	Lower Limit	Upper Limit
Evening shift	0.31	0.09	.0006	1.87	1.31	2.67
Not difficult	0.41	0.10	.0001	2.29	1.53	3.42
Cooperative child	0.30	0.09	.0008	1.83	1.28	2.61

covariates significantly affected the chance of overall success. Data analysis was complicated by the fact that multiple attempts to start the IV might have been performed by different nurses on the same child, and the same nurse might have started IVs on different children. Standard techniques allow control for one of these correlations. The authors chose to control for within-subject correlation, using generalized estimation equations modeling,[13] since it is reasonable to assume that the inherent correlation for venipuncture attempts on the same child will be greater than the inherent correlation of the same nurse starting IVs on different children.

There was a within-subject correlation of approximately 0.6 and 5 significant covariates: shift, perception of difficulty, cooperativeness of child, first attempt at the IV, and nurse experience. Table 3 shows the odds ratio estimates for variables affecting a successful IV placement, given all attempts.

What Factors Affected How Much Time the IV Start Took?

Intravenous catheter placement was ultimately successful in 93% of encounters. For the majority of these subjects, 84% of the successful attempts required 1 or 2 nurses. Because of frequent changes in nurses between venipunctures, usual repeated-measures analysis was not a viable method to analyze the data on time to successful IV placement. Proportional hazard models were used to examine the time to successful IV placement for the first and second nurses.

When looking at attempts by the first or second nurse, approximately 38% of the first-attempt nurses were self-rated as novice or advanced beginner and 32% of first-attempt nurses had less than 1 year's pediatric experience. First attempts were significantly more likely to be performed by inexperienced or less competent nurses, and second attempts were more likely to be performed by nurses with more than 3 years' experience or a proficient/expert sense of competence ($P < .0001$).

Length of time to successful IV placement and the number of attempts required were highly correlated ($r = 0.833$). Log-rank test between the first and second nurses shows a significant difference in the proportion of overall success between the first and second nurses ($P = .0047$). More time was needed if a second nurse was brought in to attempt the IV. However, the second nurse (usually more experienced) took less time to start an IV than the first nurse.

Proportional hazards modeling was used to analyze the relationship of nurse and child variables and the length of time needed to achieve a successful IV placement. Of the 502 children with IVs successfully inserted

TABLE 3

Parameters and Odds Ratios for Success With Multiple Venipunctures

Parameter	Estimate	SE	P	Odds Ratio	Lower Limit	Upper Limit
Evening shift	0.61	0.18	.0006	1.84	1.30	2.62
Not difficult	1.04	0.20	.0001	2.83	1.91	4.19
Cooperative child	0.59	0.18	.0012	1.80	1.26	2.56
1st venipuncture	1.35	0.14	.0001	3.86	2.95	5.03
Nurse experience (<1 y vs >1 y)	0.60	0.17	.0004	1.80	1.26	2.56

by 1 or 2 nurses, 473 had complete data for the explanatory variables. Three significant predictors were found for the amount of time needed to obtain a successful IV placement: perceived level of difficulty, cooperativeness of the child, and nurse competency (expert vs all others). Intravenous placement in a difficult child took significantly longer to obtain than in a child who was not perceived as difficult. Likewise, the time to successful IV insertion was significantly less for a cooperative child or an expert nurse (Tables 4 and 5).

In our assessment of the time needed to obtain a successful IV insertion based on whether 1 or more nurses have made attempts, a new potential covariate arose: the time taken by the first nurse to attempt the IV. Backward model selection, which now included this new covariate, showed only 1 statistically significant variable: nurse competency (expert vs all others). There was a statistically significant decline in the time to successful IV placement when an expert nurse took over for another nurse who had failed to start the IV (P = .005). Expert nurses needed a median of 9 minutes to start an IV, whereas all other categories of competence required a median of 19 minutes.

DISCUSSION

Using independent observations, this study was able to demonstrate that pediatric nurses with self-reported proficient or expert competence are able to start peripheral IVs in the least amount of time and with the fewest attempts. Furthermore, the child's characteristics of cooperation and difficulty of the IV attempt are the most predictive of IV success. It is important to note that many IVs are first attempted by a less-experienced nurse and more than 1 attempt may be required. If the child is perceived as uncooperative or to be a difficult IV, there is an increase in the number of attempts and the amount of time required.

We had a first-venipuncture success rate of 46% with an average of 2 attempts, requiring 20 to 30 minutes. A large portion of the study sample was infants and young children with a median age of 2 years. When analyzed as single variables, age and weight were significant to predict a successful IV start. When nurse experience and competence were added to the model, however, the effect of age and weight on time and number of attempts needed to obtain a successful IV placement were not significant. Race, sex, and weight percentiles were equally unhelpful in determining how many attempts or how much time was necessary to obtain a successful IV placement.

Experience and competence levels had no measured impact on whether an IV was successfully placed with the *first* attempt because a large portion of first venipunctures was attempted by the least experienced or novice nurses. When the first attempt failed, however, the effects of nurse competence and experience became apparent. Nurses with the least experience (less than 1 year) had the most overall difficulty in starting a successful IV placement compared with all nurses with more than 1 year's experience. Since experience did not have a significant effect in the first attempt analysis, we determined that the experience factor became important to obtaining a successful IV placement only after the first attempt failed.

In contrast to the effect of nurse experience on the number of attempts needed for successful IV placement, nurse-perceived competence affected the overall time to obtain a successful IV placement. In both the first-attempt nurse and second-attempt nurse scenarios, nurses who considered themselves experts took significantly less time than nurses in all other competency groups. The overall time needed to start an IV would be expected to be longer if more than 1 nurse was needed to obtain a successful IV placement. However, when the first nurse was a novice with little experience, the amount of time spent seeking and manipulating the IV was longer than if the first nurse was experienced, protracting the overall time to successful IV placement. The time to start the IV was less if the first attempt was made by an experienced, expert nurse.

Experience and perceived competency each appeared to have a threshold. Once the nurse reached a certain level of experience and competence, additional levels did not increase the likelihood of successful IV placement.

TABLE 4

Median Length of Time to Obtain a Successful IV Placement Based on Cooperativeness, Difficulty, and Experience

	Median Time, Minutes	*P*
Cooperative	7	<.021
Uncooperative	10	
Difficult	12	.001
Not difficult	7	
Expert	5	.003
Not expert	8	

TABLE 5

Proportional Hazards Model to Predict Length of Time to Successful IV Placement Based on Nurse and Child Variables

	Model Parameter Estimates			Adjusted Hazard Ratios		
Parameter	Estimate	SE	*P*	Odds Ratio	Lower Limit	Upper Limit
Not difficult	0.49	0.14	.0005	1.64	1.45	2.51
Cooperative child	0.26	0.12	.0219	1.30	1.05	1.64
Nurse competency (expert vs others)	0.52	0.17	.0028	1.68	1.32	2.59

Nurses with a year or more of experience are the most successful at starting IVs. Those who reach the competency level of expert can start an IV in the least amount of time.

In nearly half of the IV attempts, even though the nurse expected the child would be uncooperative, the nurse still did not expect the IV attempt to be difficult. In the final analyses, however, the only significant covariates to predict IV success were the patient characteristics of cooperativeness and degree of difficulty; these significant covariates were not related to nurse abilities.

LIMITATIONS

Our study included independent, direct observation with the goal of improving accuracy of reporting the number of venipunctures and the time needed to obtain a successful IV placement. Nevertheless, there are several limitations to the study. Not all IV insertions over the study period were observed. There is no information on how representative the observed IV attempts were compared with all IV attempts. Nurses' willingness to be observed and to notify the research personnel was arbitrary. In some cases, IVs were inserted without the research personnel being notified. A number of the enrolled nurses who were not observed worked 7:00 PM to 7:00 AM, whereas many of the observed nurses were inexperienced and worked the day shift. It is also possible that the nurses who were feeling confident were more likely to notify the research personnel to participate in a direct observation of the IV attempt.

Given real-life clinical situations, prediction of characteristics or conditions to obtain a successful IV placement continues to be imprecise. The number of venipunctures needed and the amount of time required can be partially explained by cooperativeness of the child or the difficulty the nurse expected with the IV placement. Both of these patient characteristics are *perceptions* of the nurse at the time she or he is ready to put in the IV. It is possible that the nurse did not have a good sense of either of these characteristics, particularly if the nurse was inexperienced or did not feel competent. Furthermore, the nurse may have felt some pressure to seem not vulnerable or lacking in confidence. Instead, the nurse approached the IV with a false expectation that the child would not be a difficult venipuncture even if the child was expected to be uncooperative. The nurse may have displayed more confidence than was actually felt and may also have felt compelled to approach the IV start confidently as a result of participating in the observed sessions, which by nature may create performance anxiety.

Although the results show that inexperienced nurses frequently made the first attempts at the IV, there might have been situations in which an expert nurse was requested to start the IV simply because the IV was expected to be difficult. Our data are consistent with experienced, expert nurses shortening the time and reducing the number of attempts needed. If it is a general nursing practice for less-experienced or novice nurses to make the first IV attempts, followed by a more senior nurse stepping in after the first nurse has failed, examining only the patient and nurse characteristics of the first attempt may not adequately describe the impact that experience really plays in starting IVs in difficult patients.

The statistical models used do not adequately represent all the relationships in the data because the correlation between using the same nurse and different subjects was not included. One way to assess the overall effectiveness of the logistic regression models is to use the area under a receiver operating characteristic (ROC) curve, which determines the effectiveness of a logistic model in terms of correctly predicting positive and negative outcomes. In general, the ROC curve should have an area under the curve greater than 0.50 (and preferably at least 0.75), which implies that the model makes a better prediction than random chance. For our 1-attempt model, the estimated area under the ROC curve was

0.65, and the multiple-attempt model had an estimated area under the ROC curve of 0.58. While there are several significant covariates, the areas under the ROC curves are modest at best, indicating that these models are only slightly better than random chance for predicting a successful attempt.

Other variables not measured in this study should be considered in future research to provide better correlation with successful IV placement. From this study, perceived difficulty of the venipuncture and cooperativeness of the child may be surrogates for other factors not measured. In addition, while time needed to obtain a successful IV placement was measured in this study as the time actively looking for the IV site and performing the venipuncture, this time does not include other necessary nursing time such as checking physician orders, obtaining supplies, and preparing the child and family, as well as documentation in the medical record. While these procedures may vary from patient to patient and are not included in these analyses, the time measured in this study for venipuncture only partially represents the amount of time nursing and other support staff spend placing an IV in a child.

In using survival models to examine the time to successful IV placement, an important assumption was made, which may or may not be reasonable: given an infinite amount of time, a nurse could successfully start an IV on any patient. The effects studied here deal with the majority of cases (84%) in which only 1 or 2 nurses were used. How these effects would extend to the more extreme cases in which 3 or more nurses were needed to start an IV was not analyzed for this report. There are limitations to all of the statistical models used here. Given the data's specific nuances, no single available model suited all the data.

CONCLUSIONS

Establishing a peripheral pediatric IV can be a frustrating event for the child, family, and nurse. In this study, 73% of pediatric peripheral IV attempts were successful with 1 or 2 venipuncture attempts and, 84% of the time, were successful with 1 or 2 nurses. Nurses appeared to underestimate the degree of difficulty of attaining IV placement. Efforts to gain cooperation in the child may potentially be associated with IV success. Children younger than 2 years were less likely to have a successful IV placement, and the nurses perceived that these children would be more difficult and less cooperative. For younger children, experienced, competent nurses should be used when available and the costs and benefits of an IV specialist or team considered.

The decision to start a peripheral IV in the hospitalized child is often a standard of care. Ordering physicians must be aware of the difficulty related to obtaining a successful IV placement, particularly if less-experienced nurses will perform the venipuncture. The family should be informed that more than 1 attempt, and perhaps more than half an hour, might be needed to obtain a successful IV placement, especially in the younger infant and child, who are generally difficult venipunctures and developmentally unable to be cooperative. Although most peripheral IVs are successfully placed, a small percentage may require alternative routes of access. This study again raises the question of the efficiencies and benefits of a pediatric IV team of experts if an IV is not started by the first nurse in the first or second attempt. Placement of IV catheters by inexperienced nurses is associated with increased risk of catheter-related bloodstream infections, whereas the use of specialty IV teams has been shown to be associated with reduced catheter-related infections, reduced complications, and reduced costs.[14]

Predicting success of the placement of a peripheral IV includes characteristics of the child and, to some extent, the experience of the nurse. None of the variables alone or together were able to reach the desired ROC of 0.75, however. The analysis of variables that relate to the probability of successful IV placement in children seems to point toward the nurse's perception of the difficulty of placement and of the cooperation of the child. Nevertheless, additional yet unidentified variables appear to be important in predicting successful IV placement in the pediatric patient.

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