Resource Utilization and Cost of Inserting Peripheral Intravenous Catheters in Hospitalized Children

AUTHORS
David A. Goff, MD,[1] Pamela Larsen, DrPH, DNSc, FNP,[1] Jason Brinkley, PhD,[2] David Eldridge, MD,[1] Dale Newton, MD,[1] Timothy Hartzog, MD,[3] and J. Routt Reigart, MD[3]

[1]Department of Pediatrics, Brody School of Medicine, and
[2]Department of Biostatistics, College of Allied Health, East Carolina University, Greenville, North Carolina; and
[3]Department of Pediatrics, Medical University of South Carolina, Charleston, South Carolina

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ABBREVIATION
IV: intravenous

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Address correspondence to David Goff, MD, Brody School of Medicine at East Carolina University, 3 E. 139 Brody, Department of Pediatrics, Greenville, NC 27834. E-mail: goffd@ecu.edu

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abstract

OBJECTIVE: The goal of this study was to measure the costs and difficulty in placing peripheral intravenous (IV) catheters in hospitalized children; measures of resource utilization. We measured the costs and difficulty in placing peripheral intravenous (IV) catheters in hospitalized children. This common procedure has implications for the utilization of hospital resources.

METHODS: This was a prospective, large-scale observational study in 2 southeastern US pediatric teaching hospitals evaluating 592 children needing peripheral IV catheters in the inpatient setting. The median age was 2.25 years with an age range of 2 days to 18 years. Costs were estimated by using directly measured staff time and national salary data. Analyses included costs according to patient characteristics (age, weight, dehydration, and difficulty of stick attempts), and nurse characteristics (experience in years and anticipated difficulty).

RESULTS: The median cost of the pediatric IV insertions was \$41, and 60% of the placements were obtained with the first nurse. Seventy-two percent of the children had a successful IV insertion in 1 to 2 attempts and accounted for 53% of total costs. However, the 28% of children who required ≥3 IV attempts had a cost range of \$69 to more than \$125, and they consumed 43% of the total IV costs. This subset was often <2 years old or dehydrated ($P = .0002$).

CONCLUSIONS: The insertion of peripheral IV catheters in an inpatient setting can be time intensive and requires significant skill. Our study suggests that resource utilization may improve when nurses and personnel proficient in starting peripheral IV catheters are used when the initial nurse has failed to obtain IV access. This systems improvement should result in shortened time to administration of parenteral therapies, positively improving outcomes and lessening length of stay, as well as improving patient/family satisfaction due to reduced perceptions of pain.

There is increased focus on improving clinical outcomes, improving safety, reducing costs, and maximizing patient satisfaction in today's health care environment. Perhaps because it is so commonplace and essential, the difficulty with venous access and the trauma to the child incurred in placing intravenous (IV) catheters may be underestimated. Placement of pediatric IV catheters requires a level of skill often lacking in providers in many general hospitals, emergency departments, and outpatient centers.[1,2] Previous studies concur that ~50% of IV insertions are successful on the first attempt, and on average, pediatric IVs require between 20 and 30 minutes for placement.[1–5] Personnel time is the largest cost factor in establishing a successful peripheral IV catheter.

We present data of directly observed and measured staff time to place pediatric IV catheters in the inpatient setting of children's hospitals, with costs assigned to each element of the process. These costs were studied relative to patient characteristics, including gender, age, time of day (shift), estimated level of dehydration, and the presence of support personnel. The following research questions were posed: What is the overall cost of placing a successful peripheral IV catheter by pediatric inpatient floor nurses? How is this cost associated with certain specific patient characteristics? How does cost increase when multiple nurses, support personnel, and/or child life specialists are needed?

METHODS

Sample

This large-scale observational study was conducted at 2 children's hospitals within academic medical centers in the southeastern United States with 161 and 165 children's beds, respectively. Nurses staffing the inpatient units at both medical centers provided primary support, and they started all of the peripheral IV catheters. There were no IV teams for pediatrics at either institution. Patient enrollment occurred between October 2007 and October 2008. The convenience sample consisted of 592 separate child encounters with 1135 peripheral IV attempts. Eligible subjects included any patient admitted to the pediatric inpatient services, up to 18 years of age, and included those with chronic or complex conditions. Children were excluded if they were in the newborn nursery, NICU, or PICU; transferred from the operating room (<8 hours postanesthesia); used patient-controlled analgesia; or were terminally ill. However, all children on the floor were otherwise eligible for the study, including IV restarts needed when the original IV catheters were begun in other hospital locations. Nurses at all levels of experience were eligible to participate, and 79% of the staff nurses (159 of 201) participated in the study. Usually, the primary care nurse assigned to the patient was the first to try to obtain IV access using 1 or 2 attempts, with nursing experience being a secondary consideration as described by Larsen et al.[2]

The study was approved by institutional review boards at both institutions. Informed written consent of patients, parents, and nurses was obtained before data collection.

Study Procedure

Research associates were trained with a uniform protocol, and interobserver use of pain scales and timing of events were validated. Each encounter was directly observed and timed with a stopwatch, noting total time spent by nursing, nursing assistant, and child life personnel from entering the room until completing and securing the peripheral IV. Timed observations were made for each subsequent attempt at IV insertion with the stopwatch continuing to run. Before the attempt, each nurse rated the expected difficulty of the IV placement (little difficulty or difficult) as well as their proficiency as described by Larsen et al.[2] The admitting resident physician rated the child's level of dehydration according to the modified Gorelick criteria.[6] Chart review was performed to obtain demographic information (age, race, gender, and diagnoses). Complete data were available on 552 patients and 1010 observed IV insertion attempts.

Health Care Resource Costs

Calculation of nurse and nursing assistant costs were based on salaries from the Bureau of Labor Statistics 2012.[7] Child life personnel salaries were based on the 2012 Child Life Profession Compensation Survey[8] (Table 1). An employment benefits cost of 23% was added to the hourly base salary of all staff members to reflect general hospital corporation practices. Salaries for the nurses with <1 year of experience were paid at the 10th percentile ($26 per hour), 1 to 5 years of experience paid at the 50th percentile ($38 per hour), and >5 years of experience ($46 per hour). Fixed supply costs needed for the IV placement were provided by hospital purchasing and included the costs of the IV start kit, saline flush, connector, infusion cap, tape, and gauze wrap. For older children, supplies were estimated at $5.50 for the first supply set for attempting IV access. For younger children aged <24 months, it was expected that the IV site would be secured with an arm board and gauze (adding $2.50), making the supply cost $8.00 for the initial attempt. Each additional IV attempt added $1.80 for the new catheter. Topical anesthetic, either a eutectic mixture of lidocaine and prilocaine in a cream (cost: $4) or a proprietary heat-generating topical anesthetic patch with lidocaine/tetracaine (cost: $12), was used in 14% ($n = 83$) of the children.

The total cost of each IV placement was calculated as follows:

Total cost = nurse cost (directly measured time × estimated hourly salary) + support personnel cost (directly measured time × estimated hourly salary) + fixed cost (supplies) + anesthetic cost analyses

SAS version 9.2 and JMP 9 software (SAS Institute, Inc., Cary, NC) were used for analyses. Mean and median values were calculated for overall costs. Two additional cost analyses were then

TABLE 1 Personnel Salaries Plus 23% Benefit

Category	Hourly Rate, $	Minute Rate, $
Nursing[a]		
10th percentile	26.00	0.43
50th percentile	38.00	0.63
75th percentile	46.00	0.77
Child life personnel[b]	24.00	0.40
Support personnel (nursing aide)[a]	15.00	0.25

Values are rounded to nearest dollar.
[a] Based on Bureau of Labor Statistics 2012[7] plus 23% benefits.
[b] 2012 Child Life Profession Compensation Survey[8] plus 23% benefits.

conducted. First, costs were adjusted by using regression modeling to simultaneously determine which factors significantly influenced cost. Second, the sum of the costs was used to extrapolate an overall annualized cost for hospitals that have similar patient populations. All statistical modeling used backward model selection and was validated with bootstrap resampling (used to estimate variability and bias) whenever possible. Log transformation of the data was used to assess skew. Significance was set at .05 in the original data set and at least 50% of the bootstrap resampling. For clarity, the data are presented as actual or adjusted costs.

RESULTS

Characteristics of Enrolled Subjects

The patient sample was 42% white and 47% African American; 56% of the children were male. The mean and median ages were 5.25 and 2.25 years, respectively. Age distribution was 0 to 2 years, 50%; 3 to 5 years, 13%; 6 to 11 years, 16%; and 12 to 18 years, 21%. More than 60% of encounters had successful IV placement with 1 nurse, and 84% of encounters were successful with 1 or 2 nurses. Overall, 93% of IV encounters were successful. It took an average of 2.1 venipunctures to obtain the IV placement, with 42% of attempts successful on the first attempt. We considered only the subset of 552 successful IV placements in our analysis but included an estimate of the cost of the remaining 40 unsuccessful attempts when calculating total direct costs associated with IV placement. Data comparing nursing experience, ratings of IV difficulty, and patient age distribution did not differ between the 2 children's hospitals ($n = 386$ vs 166; $P = .359$).

Total Costs of Peripheral IV Catheters

The cost analysis of this cohort includes all personnel minutes beginning on entering the room and stopping when leaving the room, plus the cost of supplies. The total patient time (elapsed minutes required to obtain the IV placement) and the total personnel time (the cumulative elapsed time of all personnel) were remarkably different and had significant effects on costs (Table 2).

Log transformation of total costs revealed a bell-shaped distribution (Fig 1). The median cost of the pediatric IV placement was $41; the 75th percentile was $57, and the 90th percentile was $85. The range of cost was skewed with a minimum of $8 and a maximum >$240. The biggest contributor to the total cost of the peripheral IV insertion was the cost of nursing, nursing assistants, and child life personnel. Sixty percent of total costs were attributable to nursing salaries and benefits, 25% for support staff, 13% for supplies, and 2% for topical anesthetics (cream or patch). All of these costs were indexed to approximate national values.

Regression Modeling

Multiple potential confounders were projected to affect the true cost of an IV placement, and regression modeling was thus used to examine potential effects of these patient characteristics. This analysis provided adjusted estimates to determine the expected cost of a particular patient characteristic with this model. Expected costs are higher than median costs because real-time scenarios take into account several elements simultaneously in a multivariate regression model.

The R^2 for the regression model was ~0.62, indicating an acceptable fit. Although personnel costs were the major driving factor of pediatric IV catheter costs, regression analyses showed that several factors were significant contributors to the cost of pediatric IV insertions, including dehydration ($P = .0002$) and age ($P < .0001$) (Table 3).

The Most Expensive Pediatric Inpatient IV Starts

Total resource costs increased significantly as more nurses and more support staff were involved, and there was an exponential relationship to time (Table 3). It took more time to establish IV access in children aged <5 years, particularly those aged <2 years, who required more attempts to obtain IV access. Children aged >5 years cost $40; those 2 to 5 years of age cost $46; and those aged <2 years cost $53. Dehydration, present in 19% of our cohort, was a significant variable (Table 4). Dehydrated young children aged <2 years increased the cost of IV attempts by $20 ($P = .0002$).

TABLE 2 Time for Successful IV Placement and Number of Nurses Required

Variable	Mean (SD)	Median	Range
IV search and place time, min[a]	12.2 (11.3)	9	1–94
Patient time in room[b]	24.3 (15.2)	20	3–117
Nursing time in room, min[c]	70.2 (78.4)	45.5	3–728
No. of nurses	2.5 (1.1)	2	1–9
No. of attempts[d]	2.1 (1.6)	2	1–9
First nurse's time, min	22.1 (13.7)	19	3–115

Data are for 552 children.
[a] Time from entering the room until successful IV access was secured.
[b] Time from entering room until completed procedure.
[c] Total combined minutes for all nursing and support staff to enter the room and accomplish the successful IV insertion.
[d] Total number of separate IV stick attempts necessary to establish a successful peripheral IV insertion.

In our entire inpatient pediatric cohort, 72% of the children had a successful IV placement in 1 to 2 attempts and accounted for 53% of total costs. However, the 28% of children who required ≥3 IV attempts had costs that increased from $69 to more than $125 and consumed 43% of the total IV costs. (Table 5)

The median cost of successfully starting the pediatric inpatient IV catheter overall was $41 in our study. However, there was a subset of 37 (6%) children with median costs of $125, nearly 3.5 times higher the rest of the cohort. This subset median time to start an IV catheter was 225 minutes compared with 42 minutes in the remainder of the cohort. The majority of these children (25 of 37) were aged <2 years (median age: 1.1 years), and 15 children were aged ≤6 months. Most of these infants were admitted with diagnoses related to infection and/or dehydration, whereas the older children in this more costly subset were likely to have a chronic condition (asthma, sickle cell disease, or neurologic conditions). Forty-six percent ($n = 17$) of children in this high-cost subset were dehydrated, compared with only 17% of children with IV attempts that cost <$100 ($P < .0001$). Furthermore, in this costly subset of children, 65% of the IV attempts were predicted by the nurses to be a difficult access a priori the first attempt, and the number of nurses involved ranged from 3 to 9 (median: 5 nurses).

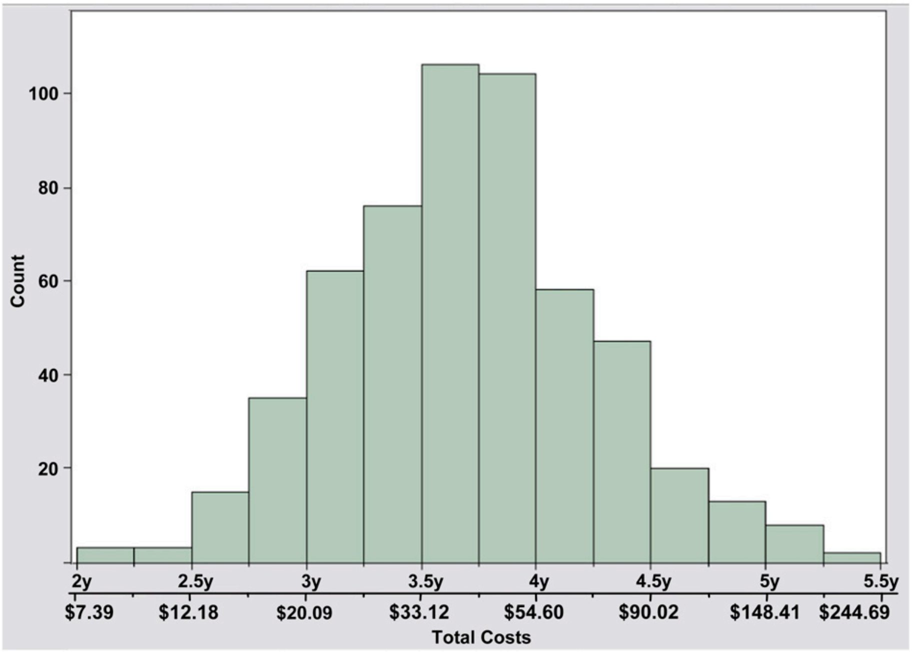

FIGURE 1 Histogram of log transformation of total cost of peripheral IV catheter placements in children.

DISCUSSION

The major findings from these analyses demonstrate that at today's costs, each pediatric inpatient peripheral IV placement performed by pediatric floor nurses has a median cost of $41, with an adjusted mean cost of $45 requiring 2.1 IV attempts. Twenty-eight percent of the time, the nurse required ≥3 IV attempts, and these costs increased to $69 to more than $125. Costs increased because more personnel were involved (nurses, assistants, and/or child life personnel). Furthermore, we identified 1 subset in which the net costs were >350% of the median IV costs.

As health care systems focus on more efficient care, 1 goal for children's hospitals, emergency departments, and other clinical settings should be to minimize the amount of time it takes to successfully insert a peripheral IV catheter in a child to achieve needed parenteral therapies and minimize the discomfort associated with this procedure. Our study suggests that identifying children who will likely involve a difficult IV placement and consume more hospital floor resources (especially nursing staff) should be handled by a redesigned group of IV insertion specialists so that this procedure can be handled more efficiently.

TABLE 3 Effect of Child and Situation Variables on the Cost of the Pediatric IV Placement ($n = 520$)

Variable	Adjusted Mean, $[a]	95% Confidence Limits, $		P
Overall	44.84	42.83	46.86	
Dehydrated				
No	42.73	37.59	48.58	.0002
Yes	49.99	43.21	57.83	
Anesthetic				
No	39.78	35.12	45.05	<.0001
Cream[b]	41.76	34.95	49.89	
Patch[c]	59.44	50.92	69.38	
Support staff				
No	42.28	36.48	48.99	<.0001
Yes	50.53	44.58	57.28	
Family present				
No	47.24	41.03	54.39	.2418
Yes	45.22	39.67	51.54	
No. of nurses involved				
1	26.02	21.99	30.79	<.0001
2	39.91	34.99	45.51	
3	58.57	51.00	67.27	
4	83.24	69.54	99.64	
Difficult stick				
No	44.23	38.80	50.43	.0208
Yes	48.30	41.94	55.61	
Gender				
Male	45.19	39.44	51.78	.1661
Female	47.27	41.36	54.01	
Age, y				
<2	53.42	46.67	61.16	<.0001
2–5	46.27	39.86	53.72	
>5	39.94	34.74	45.91	
Shift				
Day	47.83	41.84	54.67	.0422
Night	44.67	38.97	51.19	
Child life personnel present				
No	42.36	37.22	48.22	<.0001
Yes	50.42	43.60	58.31	
Race				
White	46.33	42.43	50.59	.2334
African American	50.45	46.25	55.04	
Hispanic	45.75	39.46	53.05	
Other	49.08	41.33	58.29	

[a] Means adjusted for all other factors in table.
[b] Topical anesthetic cream is a eutectic mixture of lidocaine 2.5% in 1:1 ratio with prilocaine 2.5%.
[c] Proprietary patch containing lidocaine 70 mg with tetracaine 70 mg in a heat-generating patch containing oxidizing iron powder.

Predictors of Difficulty

Our data indicate that children aged >5 years were generally an easy group in which to establish a successful inpatient IV catheter, and therefore those IV placements can usually be accomplished by general pediatric nurses. Previous research reported it took an average of 12 minutes to start a successful IV catheter[2] (recording only the time needed to search for the IV site until blood flow at the catheter). However, with children aged <5 years, especially children aged <2 years, as well as with dehydrated children, there is a significant increase in nursing and associated staff time. Nurses at both institutions noted that it is more difficult to hold young children for IV starts. In addition, Larsen et al[2] found that pediatric nurses with <1 year of experience, self-assessed proficiency of novice or advanced beginner, and those who rated the IV access to be difficult before attempting the IV placement, took significantly more time and needed more sticks to obtain insertion. In these cases, multiple nurses were often recruited to assist for 20 to ≥70 minutes.

Systems of Care

What is the most efficient system for establishing IV access in an inpatient children's hospital setting where 28% of children will require ≥3 attempts at a peripheral IV? Several studies with predominantly adult populations[10–12,16] have advocated IV teams. It is important from a clinical outcomes, financial, and family satisfaction standpoint that each health care organization carefully creates an effective system to maximize successful IV placement by selection of proficient clinicians (usually nurses), using the best techniques to improve insertion success in young children and minimize the pain of the procedure.

Ideally, we would have only our most expert nurses or health professionals with the best technical skills start all IV catheters. An IV team to place these lines in a timely manner is certainly an alternative consideration.[10,11] The concept of an IV team has long been supported[13] and may be more cost-effective.[1,10,11] Frey[1] demonstrated that expert IV nurses had significantly better success rates than resident physicians and general staff in an academic children's hospital. MacPhee[10] described a quality improvement project at the Denver Children's Hospital and concluded that venous access teams can enhance the quality of care, but that careful cost analysis is important. They developed an evidence-based, expert opinion, clinical guideline for insertion

TABLE 4 Comparison of Number of IV Attempts, Number of Nurses, and Expected Costs Based on Hydration Status

Dehydrated	Age Groups, y	No. of Children	Expected Costs, $	Average No. of Attempts	% With ≥3 Attempts	Median No. of Nurses
No	<2	194	47.12	2.31	32	2
	2.2–5	62	45.39	1.92	24	3
	>5	193	34.08	1.73	20	2
Yes	<2	60	67.06	2.67	33	3
	2.2–5	12	62.41	2.75	50	3
	>5	31	46.25	2.06	32	2

of all IV catheters, including a focus on which children were early candidates for peripherally inserted central catheters or central venous catheters.

Many staffing models use nurses to start the majority of peripheral pediatric IV catheters. To minimize costs, our study suggests that the most proficient nurses should be assigned to attempt the more difficult IV placements; that is, those in young infants, children aged <5 years, dehydrated children, and children expected to be a difficult venipuncture. Larsen et al[2] showed that experienced floor nurses have a higher success rate and placed the IV catheter in less time. With this "expert clinician" model, one would expect faster time to deliver antibiotics and IV therapies, a reduction in procedures that require IV access, fewer delays in patient care, improved continuity of nursing assignments, improved patient and family satisfaction, and potentially decreased length of stay.

Annualized Costs

To better understand the broader financial impact of pediatric peripheral IV placements, annualized costs were examined by using 2009 national nursing salaries and prevailing supply costs. As an example, if a hospital with a 30-bed inpatient pediatric unit averages 6 peripheral IV starts per day, there would be 2200 peripheral IV starts per year. Based on our data, an estimate of the total costs for the 72% of the 2200 IV placements with 1 to 2 attempts is ~$71 100 ($45 × 1580). Our findings predict that 28% of children will require ≥3 attempts at a cost of at least $69 per child ($69 × 616) or $42 504 in additional costs for that subset of children. This estimate would lead to an annualized total cost of $113 600. These annualized costs do not include the opportunity costs associated with nurses pulled away from their other duties while starting IV catheters. We believe that the estimates provided here are conservative. Given the expenses associated with IV placements, it is easy to see that the potential annualized costs could vary greatly in different hospital settings depending on acuity of the patients and skill of the nurses.

Limitations

The limitations to this study include it being conducted only on children's units with trained pediatric nurses, possible nursing selection bias, and patient acuity. Pediatric IV starts in the emergency departments were not included in this study, but IV restarts on the floor were included. Both of our children's hospitals included a moderate number of admissions from the immediate surrounding communities with less illness morbidity. The lower acuity in our study group combined with a high level of pediatric nursing IV skills should theoretically underestimate the percentage of children with difficult IV access. In addition, only 19% of the children used for analysis were assessed as dehydrated. During certain seasonal illnesses, this percentage of dehydrated children may be considerably higher.

There was a potential selection bias in which the most experienced nurses might be selected to attempt placements in the more difficult patients, and this selection again may overestimate the success rates. In this study, the nurses work only on the pediatric units and many have considerable technical skills starting peripheral IV catheters in children. Larsen et al[2] noted that nursing experience of >1 year was an independent predictor of IV success. There are many hospitals both regionally and nationally who do not have specific dedicated pediatric nurses. This lack of pediatric IV nursing skills would significantly increase cost estimates because more nursing time and number of IV attempts have an exponential relationship to cost.

CONCLUSIONS

Many children admitted to a children's hospital have a need for IV access, most commonly to provide antibiotics and often IV hydration. One solution

TABLE 5 Comparison of Costs for Children With ≥3 IV Attempts

No. of Attempts	No. of Children	Median Age, y	Child Life Personnel Present, %	Support Personnel Present, %	Anesthetic Use, %	Median Cost, $
1–2	399	3.0	18.6	76.9	15.5	35.12
≥3	153	1.6	14.4	76.5	11.1	68.54

to the resource issue of IV access is to manage some pediatric floor admissions without the need for IV access. The rapidly rising health care costs in the United States have motivated us to focus on systems of care to provide the best clinical outcomes as well as efficient, cost-effective care. In this study, 28% of the enrolled children required ≥3 attempts at placement, with a median cost of $69 per patient; this $42 504 accounted for 37% of the annualized $113 600 IV access cost on a single 30-bed inpatient unit. This figure would increase as the IV expertise of nurses is lower, the number of inpatient children aged <2 years rises, or the rates of admissions with dehydration rise. This more costly subset of children requires a thorough, systems-based approach to accomplish successful peripheral IV placement. When IV therapies are required, the time from admission to successful IV insertion translates into earlier antibiotic administration or rehydration, both metrics of quality and safety, and will likely shorten the length of stay. Shortening the time nurses and other staff spend starting IV catheters creates more time for direct patient-centered nursing care. In addition, IV access is the most common painful procedure in a children's hospital,[15] and the goal of our health care system should be to minimize child discomfort and thus improve patient/parent satisfaction.

Proficient pediatric IV nurses (or technicians) and/or venous access teams would likely be an effective and efficient solution. A multicenter prospective trial should compare routine children's hospital nurse IV insertions (as the current study described) with an algorithm that triages children considered as more difficult IV access that is supported by a team of proficient experienced clinicians. This analysis would help clarify the clinical efficiency and effectiveness question in pediatric medicine. Improving time to IV access should improve quality and safety of care of children in the inpatient setting, as well as the hospital experiences for children and their parents, and allow nurses to provide more bedside nursing care. Improving clinical outcomes and concomitantly decreasing health care costs is one aim of well-designed health care systems.

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