Effect of Adding a Pediatric Vascular Access Team Component to a Pediatric Peripheral Vascular Access Algorithm

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Introduction: Intravenous (IV) placement outcomes in pediatric patients need to be improved. The purpose of the study was to examine if a pediatric peripheral vascular access algorithm with a pediatric vascular access team (PPVAA-VAT) improved IV placement outcomes compared with Pediatric Peripheral Vascular Access Algorithm (PPVAA)-alone use.

Methods: This study was a prospective, comparative, two-group design of hospitalized children. Multivariable logistic regression models were used to evaluate differences between cohort outcomes.

Results: The PPVAA-alone IV attempts ($n = 302$) were followed by PPVAA-VAT attempts ($n = 294$). First attempt and overall IV success were higher in the PPVAA-VAT group after adjusting for confounding patient characteristics ($p < .001$ and $p = .002$, respectively). The IV attempts and staff required per encounter decreased in the PPVAA-VAT vs. PPVAA-alone group.

Discussion: The PPVAA-VAT group had greater first attempt and overall IV success, and was more likely to have fewer attempts and staff involved in IV access encounters. J Pediatr Health Care. (2020) *34*, 4−9

KEY WORDS

Children, intravenous, IV start, IV difficulty, IV placement success

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INTRODUCTION

Vascular access can be a lifesaving procedure for hospitalized children; however, success rates have not improved over time (Carr, Higgins, Cooke, Mihala, & Rickard, 2018; Parker, Benzies, & Hayden, 2017). Multiple vascular access attempts (Carr et al., 2018; Kuensting et al., 2009) may increase children's stress and anxiety (Stoltz & Manworren, 2017) despite use of comfort positioning, topical analgesia, and most distraction techniques (Birnie, Noel, Chambers, Uman, & Parker, 2018). A bundled intervention may lead to better intravenous (IV) access outcomes than stand-alone interventions. In one bundled algorithm intervention, called the Pediatric Peripheral Vascular Access Algorithm (PPVAA), vascular access was defined as a process, rather than as a task. The algorithm included the following four components aimed at ensuring the best outcomes with the least distress to children: comfort plan, pediatric IV difficulty score (PIDS), nurses' self-assessed IV access ability, and stopping-the-line (Hartman, Baker, Bena, Morrison, & Albert, 2018). A recent study (Hartman et al., 2018) reported that overall IV success rate decreased in the post-PPVAA period, which suggested that IV access clinicians stopped-the-line when IV access was futile. Furthermore, it was shown that nurses' self-assessed IV competency did not improve overall IV success or first attempt success (Hartman et al., 2018; Larsen et al., 2010). These data indicated that there may be a difference between dedicated experts (defined as nurses with advanced vascular access knowledge and skills who are board certified in vascular access and demonstrate consistent excellence in IV placement) and clinicians who believe they are experts at initiating vascular access (defined as nurses with self-perceptions of competency, but without advanced vascular access knowledge, board certification or consistent excellence in IV placement; Carr et al., 2018).

Vascular access teams (VAT) are nurses with an expertise in vascular access that may improve outcomes in IV starts. However, in a recent quality improvement study of 1579 IV attempts from 1,111 patients, the overall success rate for VAT was only 59.4%; this was despite having access to visualization and palpation, near infrared light, ultrasound, and transillumination techniques. Importantly, overall IV success rate improved to 84.3% for VAT nurses within three attempts (Elkhunovich et al., 2017). Although VATs are discussed in the literature as best practice (Harpel, 2013; Kuensting et al., 2009), strong research evidence is lacking to support this conclusion. In a recent review of 2,398 potential studies, there were no randomized controlled trials identified. Most reports involved central venous catheter placement (not peripheral IV catheter), quality improvement, insertion techniques, distraction therapies, and complications (Carr et al., 2018; da Silva, Priebe, & Dias, 2010).

Dedicated VATs may be better able to address vascular access as a process, especially if part of an algorithm. When using a PPVAA, it is unknown if a VAT improves IV placement and decreases patient's distress (as measured by number of IV access attempts) compared with pediatric clinical nurses with self-assessed expertise. As such, the aims of this study were as follows: (1) to determine if use of PPVAA-alone (included clinical nurses with multiple levels of IV expertise) or PPVAA with a VAT increased first attempt and overall peripheral IV success; (2) to determine if use of PPVAA-alone or PPVAA with a VAT decreased the number of clinicians used and overall attempts per episode (defined as the period that IV access was attempted by one or more staff); and, (3) to determine the differences in first IV attempt, overall peripheral IV success, number of staff used to attempt IV access, and overall IV attempts per episode in the post-VAT implementation period based on VAT availability.

METHODS

Design

This study used a prospective, two-group, pre- and post-intervention, comparative design with sequential sampling and an intent-to-treat analysis plan (aims one and two). An intent-to-treat analysis plan included patients who met eligibility criteria in the post-intervention period, regardless of the intervention fidelity. This analysis plan was representative of real-world practices. Intervention non-adherence was because of unavailability of a VAT nurse when needed or clinical nurses' decisions to continue attempting IV access despite PPVAA criteria for escalation to a more expert clinician. The Cleveland Clinic Institutional Review Board approved this study before initiation. Patients received usual care or enhanced usual care (VAT) by nurses and were not required to provide informed consent. Nurses who participated provided written informed consent.

Setting and Sample

The setting was a 120-bed children's hospital on the main campus of the Cleveland Clinic, a quaternary care healthcare system in Northeast Ohio. The samples were pediatric patients who received peripheral vascular access attempts as prescribed and as recorded by clinical nurses. Patients who participated were hospitalized on five medical-surgical pediatric units that included specialty care (i.e., hematology-oncology, epilepsy, cardiac or gastrointestinal transplantation, and respiratory conditions).

Intervention

The intervention involved the use of the PPVAA with a dedicated VAT (PPVAA with VAT) to initiate peripheral IV. The VAT was composed of three pediatric clinical nurses with vascular access board certification and expertise in peripheral IV initiation. Primary responsibilities were initiation, assessment, and maintenance of peripheral and central IV lines. They were scheduled from 7:00 a.m. to 6:00 p.m. on weekdays. Nurses staggered their start times to provide coverage based on unit needs; however, no coverage was available on weekends and holidays.

In the pre-intervention period, clinical nurses used the PPVAA-alone to initiate peripheral IVs. As previously described (Hartman et al., 2018), PPVAA has four components, including patient comfort, pediatric IV difficulty score, nurses' level of expertise in vascular access, and escalation of IV start to a more expert person (i.e., stopping-the-line). Generally, when patients needed an IV clinical nurses used the PPVAA to determine if their clinical expertise matched patients' IV difficulty level. The PPVAA was used to escalate an IV attempt to a more experienced provider when there was a mismatch between nurse expertise and patient IV difficulty level. Pediatric intensive care clinical nurses with expertise in vascular access, anesthesiologists, pediatric certified nurse anesthetists, and critical care transport team members were all considered experienced providers. However, there was no dedicated team in place and there were occasions when an expert was not available. Between the pre- and post-intervention periods, a six-month gap was used for VAT program development and initiation.

Outcome Measurement and Data Collection

IV start success was assessed using the following four metrics: first attempt peripheral IV success, overall IV attempts per episode, number of staff attempting IV access, and overall number of IV attempts per episode. All four outcomes were measured using an investigator-developed case report form that was completed by the nurse attempting an IV start. When more than one clinician attempted an IV during the same episode, a new form was initiated. This tool has face and content validity (Hartman et al., 2018).

Each patient's IV difficulty score was calculated by the patient's clinical nurse using the PIDS, a six-item tool that was adapted from the Assessment Tool for Grading IV Access (Catudel, 1999). Each item represented a factor related to IV attempt difficulty in children. The sum score range was seven to 21, with higher scores equating to greater IV start difficulty. In analysis, scores were grouped into three categories based on IV access difficulty: 7-10 (low), 11-13 (moderate), and equal to or greater than 14 (high). Based on expert consensus, PIDS had face and content validity, and construct validity was confirmed in this study by comparing vascular access success based on PIDS score categories.

In the post-VAT period, assessment of VAT availability was based on IV attempt date and time. All attempts on weekends, holidays, or between the hours of 6:01 p.m. and 6:59 a.m. were considered non-VAT attempts in analysis. When the VAT team was on duty, they were considered available to attempt IV access, regardless if they were not used. Patient demographics included age, gender, race, primary diagnosis category, and IV start (initial or restart). Demographics data were extracted from an administrative database.

Data Analysis

To determine relationships between groups, categorical variables were assessed using chi-square (χ^2) tests. Ordered data were assessed using Wilcoxon rank sum tests. Continuous variables were assessed using *t*-tests or Wilcoxon rank sum tests. Ad hoc comparisons were performed where appropriate. Comparisons between groups on the proportion of episodes with five or more attempts and among episodes resulting in a success were performed using Pearson χ^2 tests. Comparisons of number of attempts, grouping the number of attempts of five or more as a single level, were performed with Wilcoxon rank sum tests. Multivariable logistic regression models were used to evaluate the differences between groups. Models were fit to allow for adjustment of IV grade when comparing groups. Analyses were performed, and graphs were created using SAS, version 9.4 (SAS Institute, Inc., Cary, NC).

RESULTS

There were 596 IV attempts made during a 12-month period (6 months pre- and 6 months post-VAT implementation). The PPVAA-alone and PPVAA with VAT groups differed in that PPVAA with VAT children were younger, less likely to be Caucasian, and had higher PIDS (Table 1).

Differences Between Algorithm Alone and Algorithm With Vascular Access Team

Compared to PPVAA-alone use, first attempt and overall IV success increased after VAT implementation (52.0% vs. 67.7%, $p < .001$; and 89.4% vs. 95.6%, $p = .006$, respectively). In an unadjusted model, the odds of first attempt IV success were increased by 94% after the VAT was added to the PPVAA. After adjusting for patient age, race, and PIDS, the odds ratio of first attempt success was increased relative to the unadjusted model. This suggested that despite higher PIDS the first attempt success remained increased (Table 2). In an unadjusted model, odds of overall IV success were 156% higher in the PPVAA with VAT group than that in the PPVAA-alone group. After adjusting for patient factors, the odds ratio of overall success was increased relative to the unadjusted model (Table 2).

TABLE 1. Patient demographics

Factor *n* (column %) except where stated otherwise	Total ($n = 596$)	PPVAA-alone ($n = 302$)	PPVAA w VAT ($n = 294$)	*p*
Age, years; mean (SD)	8.4 (6.8)	9.0 (6.8)	7.8 (6.8)	.042[a]
Gender, female	301 (50.5)	154 (51.0)	147 (50.0)	.81[b]
Race; Caucasian	431 (72.3)	234 (77.5)	197 (67.0)	.004[b]
Pediatric Intravenous Difficulty Score				.012[c]
7–10	226 (37.9)	129 (42.7)	97 (33.0)	
11–13	202 (33.9)	98 (32.5)	104 (35.4)	
≥14	168 (28.2)	75 (24.8)	93 (31.6)	
Diagnosis[d]				.40[b]
Gastrointestinal	91 (15.4)	48 (15.9)	43 (14.8)	
Hematology/oncology	31 (5.2)	16 (5.3)	15 (5.2)	
Neurology	223 (37.7)	117 (38.7)	106 (36.6)	
Respiratory	55 (9.3)	21 (7.0)	34 (11.7)	
Other	192 (32.4)	100 (33.1)	92 (31.7)	

Note. *PPVAA, Pediatric Peripheral Vascular Access Algorithm; VAT, vascular access team; w, with.*
[a]t-*test.*
[b]*Pearson's χ^2 test.*
[c]*Kruskal–Wallis test.*
[d]*Data not available for all subjects, diagnosis missing = 4.*

TABLE 2. First attempt and overall IV success for PPVAA-alone and PPVAA with VAT

IV success	Factor	Unadjusted model			Adjusted model		
		Odds ratio (95% CI)	Level *p*	Overall *p*	Odds ratio (95% CI)	Level *p*	Overall *p*
1st attempt	PPVAA w VAT vs. PPVAA-alone	2.56 (1.32, 4.99)	.006	.006	3.04 (1.53, 6.03)	.002	.002
	Age (per year)				1.03 (0.98, 1.09)	.26	.26
	Non-White Race				0.90 (0.43, 1.87)	.77	.77
	PIDS: 11−13 vs. 6−10				0.21 (0.08, 0.61)	.004	.010
	PIDS: ≥14 vs. 6−10				0.20 (0.06, 0.61)	.005	
Overall	PPVAA w VAT vs. PPVAA-alone	1.94 (1.39, 2.70)	<.001	<.001	2.44 (1.69, 3.52)	<.001	<.001
	Age (per year)				1.01 (0.98, 1.04)	.70	.70
	Non-White Race				0.70 (0.47, 1.05)	.082	.082
	PIDS: 11−13 vs. 6−10				0.24 (0.15, 0.38)	<.001	<.001
	PIDS: ≥14 vs. 6−10				0.16 (0.10, 0.29)	<.001	

Note. *CI, confidence interval; IV, intravenous; PIDS, Pediatric Intravenous Difficulty Score; PPVAA, Pediatric Peripheral Vascular Access Algorithm; VAT, vascular access team; w, with*.

The number of clinicians involved in pediatric IV access attempts and overall IV attempts per episode were examined (Table 3). There were fewer IV start episodes that required more than one clinician in the PPVAA with VAT compared with PPVAA-alone group (9.8% [$n = 29$] vs. 24.8% [$n = 75$], $p < .001$, respectively). In addition, the overall number of IV attempts per episode, regardless of the number of clinicians who attempted, was reduced in the PPVAA with VAT vs. PPVAA-alone group ($p < .001$).

In the post-VAT period, the VAT was not available for IV access attempt around-the-clock. Thus, outcomes for the PPVAA with VAT group ($n = 294$) were differentially affected by VAT presence. To address this phenomenon, the PPVAA with VAT group were divided into two subgroups: VAT member available to attempt IV access ($n = 135$; VAT available) and VAT member not available because of weekend, holiday, and night shift hours ($n = 159$; VAT not available). These subgroups were then compared with the PPVAA-alone group. First attempt success and overall IV success rate was greater in the PPVAA with VAT available group (Table 4). The number of clinicians attempting IV access was lower in the PPVAA with VAT available group than in PPVAA-alone and PPVAA with VAT not available groups. Furthermore, the overall IV access attempts were lower in the PPVAA with VAT available vs. PPVAA-alone group (Table 4).

DISCUSSION

The PPVAA was designed to direct pediatric vascular access initiation as a safe and reliable process to enhance IV success. When PPVAA was accompanied by VAT availability, the first attempt and overall IV success rate were increased, regardless of patient IV start difficulty. First attempt IV success is an important goal of the PPVAA process since it may decrease the risk of pain and bruising at insertion sites and the risk of a bloodstream infection (Birnie et al., 2018; Kelly, Russell, Devgon, & Rosen, 2017; Mermel, 2017). No previous studies were published on pediatric IV starts that included a 4-factor algorithm to achieve improved first attempt and overall IV success. The benefits of using a VAT were assessed in a Cochrane systematic review, but the low strength of evidence prevented authors from completing the

TABLE 3. Intravenous access attempts between PPVAA-alone and PPVAA w VAT

Factor *n* (column %)	Total ($n = 596$)	PPVAA-alone ($n = 302$)	PPVAA w VAT ($n = 294$)	p^a
Clinicians attempting per episode				<.001
1	492 (82.6)	227 (75.2)	265 (90.1)	
2	81 (13.6)	58 (19.2)	23 (7.8)	
3 or more	23 (3.9)	17 (5.6)	6 (2.0)	
Number of attempts per episode				<.001
1	373 (62.6)	170 (56.3)	203 (69.0)	
2	125 (21.0)	66 (21.9)	59 (20.1)	
3	55 (9.2)	37 (12.3)	18 (6.1)	
4	25 (4.2)	18 (6.0)	7 (2.4)	
5+	18 (3.0)	11 (3.6)	7 (2.4)	

Note. *PPVAA, Pediatric Peripheral Vascular Access Algorithm; VAT, vascular access team; w, with.*
[a]*Wilcoxon rank sum test.*

TABLE 4. The relationship between PPVAA-alone and PPVAA w VAT outcomes based on VAT availability

		PPVAA w VAT program in place		PPVAA-alone	
Factor	**Total (*n* = 596)**	**VAT not available (*n* = 159)**	**VAT available (*n* = 135)**	**(*n* = 302)**	***p*[a]**
First attempt success, yes	356 (59.7)	100 (62.9)	99 (73.3)[b]	157 (52.0)[c]	<.001[d]
Overall IV success rate	551 (92.4)	151 (95.0)	130 (96.3)	270 (89.4)	.016[d]
Staff attempted, median (range)	1 (1–5)	1 (1–5)[b,c]	1 (1–2)[b,e]	1 (1–4)[c,e]	<.001[f]
Staff attempted per episode					<.001[d]
1	492 (82.6)	136 (85.5)[c]	129 (95.6)[b,e]	227 (75.2)[c]	
2	81 (13.6)	17 (10.7)	6 (4.4)	58 (19.2)	
3 or more	23 (3.9)	6 (3.8)	0 (0.0)	17 (5.6)	
IV attempts, median (range)	1 (1–11)	1 (1–11)	1 (1–4)[a]	1 (1–9)[b]	<.001[e]

Note. *IV, intravenous; PPVAA, Pediatric Peripheral Vascular Access Algorithm; VAT, vascular access team; w, with.*
[a]*Statistics presented as median (range) or N (column %). A significance level of 0.017 was used for pairwise ad hoc comparisons.*
[b]*Significantly different from PPVAA-alone.*
[c]*Significantly different from PPVAA w VAT available.*
[d]*Pearson's chi-square test.*
[e]*Significantly different from PPVAA-VAT not available.*
[f]*Kruskal–Wallis test.*

review (Carr et al., 2018). Although this report is not a randomized controlled trial, it compared two groups of children who required IV access and adjusted between group results to address differences in IV start difficulty and patient characteristics. Additional research is needed to determine if a PPVAA with VAT approach can result in similar IV access improvements.

In our study, fewer clinicians attempted IV access per episode when the PPVAA was accompanied with a VAT. The benefits of completing the IV access process with fewer clinicians can include reduced resource use and cost associated with personnel and supplies, as well as greater time to focus on direct patient-centered care (Goff et al., 2013). Clinicians have assessed the value of using biomedical devices to enhance first attempt and overall IV success, such as infrared technologies. However, data from a recent randomized controlled trial demonstrated that these devices did not improve IV placement success. Moreover, the authors advocated for building nurses' skills and confidence in IV insertion (McNeely, Ream, Thrasher, Dziadkowiec, & Callahan, 2018).

The PPVAA process takes a different approach toward IV success. Rather than considering IV initiation a task, nurses use a written guide to determine if their skill/competency matches patients' vascular access initiation needs. Since nurses are matched based on patients' needs, nurse satisfaction for the IV access procedure may be enhanced, and patients and their families may be more satisfied with care delivery. Additional research on the PPVAA with VAT is needed to determine potential nurse- and patient/family-related benefits beyond success rates. This work is especially important considering the cost to maintain a VAT.

This research study had several limitations. We used a single site at an urban, quaternary care medical center. Our acuity was very high and other pediatric hospital/healthcare sites may not have similar results. Clinical nurses provided data on PIDS, the number of IV attempts made and, IV success. Although most nurses participated, this study used a convenience sample. It is unknown if nurses who failed to provide data had different vascular access attempt experiences than those who provided data. Errors on data collection forms may have biased findings. The level of expertise in IV placement by clinical nurses varied. Some nurses may have perceived themselves to be experts, but their actual competence may not have matched the level of expertise among VAT nurses. Alternately, clinical nurse perceptions of vascular access expertise could have been low, but in fact, they were extremely competent. In this study, IV access success was defined by flashback of blood in the IV hub with no signs of infiltration when administering a normal saline flushing solution after IV placement. However, success was not measured by the length of time the IV maintained patency. Finally, visualization and palpation tools in the marketplace were available to all nurses and potentially used during vascular access attempts. In this study, we did not collect data on technological use. As such, future studies will need to address use of IV access technology by VAT personnel.

CONCLUSION

When PPVAA was applied using a VAT, IV access results were improved in comparison with clinical nurses with variable vascular access competency levels. Research on use of the PPVAA with VAT provides new data on the value of designated vascular access experts as part of an algorithm. Hospital leadership should encourage use of a formal process of IV initiation in children that includes a designated VAT and assess performance of first attempt and overall IV success to determine if this approach can prevent a million unnecessary pokes.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.pedhc.2019.06.004.

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