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ORIGINAL RESEARCH

Characterization of the Difficult Peripheral IV in the Perioperative Setting: A Prospective, Observational Study of Intravenous Access for Pediatric Patients Undergoing Anesthesia

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Background: Various criteria exist for defining difficult intravenous access (DIVA) in infants and children. The current study evaluated the factors associated with DIVA in a prospective cohort of over 1000 infants and children presenting for anesthetic care.

Methods: This was a prospective, observational study of patients aged 0 to 18 years undergoing elective surgical or radiologic procedures under general anesthesia. Prior to the initial attempt at peripheral intravenous (PIV) cannulation, the anticipated difficulty of PIV catheter placement was determined by the provider using a visual analogue scale (VAS) from 1 to 10. The number of attempts was recorded as well as the time required to achieve PIV access. DIVA was defined as requiring three or more attempts. After successful cannulation, the actual difficulty of the PIV placement was assessed by the provider and recorded using the same VAS. Patient characteristics, including age, race, body mass index (BMI), American Society of Anesthesiologists (ASA) physical classification, and history of difficult PIV placement, were evaluated as covariates.

Results: In our cohort of 1002 pediatric patients, 78% of patients were successfully cannulated in a single attempt and 91% of patients were successfully cannulated in two or fewer attempts. Factors associated with requiring three or more PIV attempts included younger age (OR 8.73; 95% CI: 3.38, 22.6 for age <1 year and OR 4.93; 95% CI: 2.05, 11.8 for age 1–3 years), higher ASA physical classification (OR 1.95; 95% CI: 1.10, 3.46 for ASA II), and prior history of difficult PIV placement (OR 3.46; 95% CI: 1.70, 7.08). BMI, racial category or gender were not independent predictors of DIVA.

Conclusion: We found that approximately 9% of patients required three or more attempts at IV placement in the operating room. Patients that required multiple PIV attempts were more likely to be younger, have a higher ASA classification or a history of difficult PIV placement.

Keywords: intravenous cannulation, pediatric anesthesiology, vascular access, peripheral intravenous catheter

Introduction

Establishing peripheral intravenous (PIV) access is one of the most common procedures in pediatric anesthesiology. Intravenous cannulation is indicated in the hospital setting and perioperative period for the administration of fluids, medications, and blood products. Although it is a common procedure, successful PIV cannulation may sometimes be challenging for health care providers. Although recent studies have sought to implement algorithms in the pediatric population to improve PIV cannulation success rate,[1] there are limited resources to guide PIV insertion decisions in patients with difficult IV access, and there is not a consensus regarding identification and management of children with difficult IV access (DIVA).[2] A previous study reported a 73% first attempt success rate for obtaining peripheral IV access in children in the operating room;[3] however, multiple attempts may be required based on various factors.

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In the perioperative setting, difficulties with establishing PIV access may contribute to delays in completing procedures, or result in the need to postpone or even cancel the scheduled anesthesia encounter. Multiple attempts at PIV cannulation prior to the induction of general anesthesia may result in significant pain and anxiety for patients and their families.[4] Additional morbidity previously reported to occur following multiple attempts at PIV placement includes nerve damage, thrombophlebitis, hematoma formation, and extravasation of intravenous fluids and medications.[4–8] When peripheral IV placement is delayed during the induction of anesthesia in smaller infants and neonates, hemodynamic instability may result from prolonged administration of volatile anesthetic agents, or there may be a risk of gastric air insufflation, with potential for regurgitation and aspiration of gastric contents.[9–11] Failure to achieve IV access may also lead to the need for more invasive procedures such as placement of an intraosseous needle or a central venous catheter.[10]

The incidence of DIVA in children has been described in the emergency department (ED) setting, leading to development of a DIVA scoring system for predicting success of PIV catheter placement on the first attempt.[12] However, there are limited data involving the incidence and predictors of DIVA for pediatric patients in the operating room and perioperative setting. This prospective, observational study evaluates the incidence of DIVA and factors associated with it during surgical and radiologic procedures in all anesthetizing locations in a freestanding tertiary-care children's hospital.

Methods

The study was conducted in accordance with the ethical principles of the Helsinki declaration. The study was reviewed and approved by the Institutional Review Board (IRB) of Nationwide Children's Hospital with unique identification NCT03591016. The study was registered with Clinicaltrials.gov as "Prospective Observational Study of Difficult Intravenous Access in the Operating Room". Written informed consent was obtained from the parent or legal guardian, and assent from the patient when age appropriate. This study was conducted between June 2018 and March 2021. Patients between 0 and 18 years of age, scheduled for surgical or radiologic procedures requiring general anesthesia were eligible for enrollment. Patients with pre-existing PIV access were excluded from study enrollment. This was strictly an observational study as there was no change in the conduct of the anesthetic care including premedication, anesthetic induction technique, or anesthetic agents administered. The attending anesthesiologist also determined whether the initial attempt to obtain PIV access was made with the patient awake, following the administration of premedication (oral midazolam), during the administration of nitrous oxide, or after the induction of anesthesia with volatile anesthetic.

Prior to the initial attempt, the anticipated difficulty of PIV placement was evaluated by the provider using a visual analogue scale (VAS) from 1 to 10, with 1 recorded as least challenging, and 10 as most difficult. A member of the research staff, uninvolved with patient care, observed the number of cannulation attempts and the overall time required to achieve PIV access. A cannulation attempt was counted if the patient's skin was punctured by a cannula. The time to achieve cannulation started when the initial tourniquet was placed, and ended when a tourniquet was released following successful cannulation or final attempt at cannulation. Additional information was captured during each attempt including catheter type and gauge size, site of attempted access, vein landmarks (visibility or palpability), use of ultrasound guidance for IV placement, the role of the individual participating in patient care securing PIV access (anesthesiology attending, Certified Registered Nurse Anesthetist [CRNA], trainee, and student), and the declared years of experience given by the participating provider. The word trainee was applied to fellows and residents. Students included medical students, and student nurse anesthetists (SRNAs). Number of attempts made, calls for help by the provider, or use of ultrasound equipment were also noted. Upon successful cannulation, the actual difficulty of the PIV placement determined by the cannulating provider was recorded using the same VAS scale from 1 to 10.

Patient characteristics and demographics were retrieved from the electronic medical record. This included age, gender, race, height, weight, body mass index (BMI), and American Society of Anesthesiologists' (ASA) physical status. The ASA physical status is a categorization tool which anesthesiologists use to indicate an individual patient's perioperative health. ASA class 1 represents a healthy patient without medical comorbidities, and ASA class 4 represents a patient with severe systemic disease that is a constant threat to life.[13] Relevant patient IV history was also recorded if known, such as a prior history of difficult PIV placement, previous ultrasound-guided peripheral IV placement, instances of anesthetic event within the preceding week requiring IV access, previous PIV placement by a specialized consult IV

team, and whether the patient had a pre-existing but non-functional PIV. All data collected or analyzed during this study are included in the manuscript. Individual, de-identified data are available from the corresponding author upon request.

Statistical Analysis

Number and percentage were calculated for all categorical variables. Median and interquartile range (IQR) were calculated for all numerical variables. Groups were compared using Wilcoxon test or Fisher's exact test where appropriate. Multivariable logistic regression was used to calculate odds ratios (ORs) and 95% confidence intervals (CI) for predictors of DIVA cannulation, defined as three or more attempts. SAS 9.4 (Cary, NC) was used for all statistical analyses.

Results

The study cohort included 1002 patients, ranging in age from 0 to 18 years, 842 of whom had their IV placed in the operating room, with the remainder being in other anesthetizing locations including cardiac catheterization suites, procedure rooms, dental operating rooms, and magnetic resonance imaging (MRI) induction suites. Demographic information of the study cohort is presented in Table 1. Nine percent of patients were infants, 49% were between the ages of one and five years, and the remaining 42% were six years of age or older. Five percent of the total study population had a history of difficult IV placement during previous anesthesia encounters. Twenty-nine percent of patients were classified as ASA I, 58% ASA II, 12% ASA III, and 1% ASA IV. Overall DIVA rate, defined as three or more attempts, was 9%.

Table 1 Demographic Information

Variable	Median (IQR) or Number (%)
Age (years)	5 (2, 9)
<1 year	94 (9%)
1–3 years	310 (31%)
4–5 years	179 (18%)
6–9 years	200 (20%)
10–12 years	108 (11%)
13–15 years	63 (6%)
≥16 years	48 (5%)
Weight (kg)	19.5 (13, 34)
Height (cm)	110 (88, 136)
Body mass index (kg/m^2)[a]	17 (15, 21)
Gender (female/male)	435 (43%) – 567 (57%)
Race	
White	740 (74%)
Black or African American	157 (16%)
Other	105 (10%)
ASA physical status (I, II, III, IV)	293 (29%) - 582 (58%) −120 (12%) - 7 (1%)
History of previous difficult IV placement	47 (5%)
Patient had an IV within the past week	12 (1%)
Number of Attempts	
One	783 (78%)
Two	131 (13%)
Three	56 (6%)
Four	20 (2%)
More than four	12 (1%)

Notes: Data are reported as the number (%) or median (interquartile range). [a]BMI does not include those under 2 years of age.
Abbreviations: IV, intravenous; IQR, interquartile range; ASA, American Society of Anesthesiologists.

Table 2 demonstrates various patients factors and the respective odds ratios for DIVA, as defined by three or more attempts at cannulation. Compared to the reference group of patients between the ages of 6 and 9 years, patients under the age of one (OR 8.73; 95% CI 3.38, 22.6) and patients between the ages of 1 and 3 years (OR 4.93; 95% CI 2.05, 11.8) were significantly more likely to be classified as DIVA. Compared to ASA I patients, patients that were classified as ASA II had significantly increased odds of requiring three or more (OR 1.95, 95% CI: 1.10, 3.46) attempts at cannulation. ASA III or IV patients also had a higher odds ratio of requiring three or more (OR 1.97; 95% CI 0.92–4.24) attempts at cannulation. Patients with a prior history of difficult PIV placement were also more likely to require three or more attempts (OR 3.46; 95% CI 1.70–7.08) Figure 1 is a visual plot of risk factors with odds ratios for 2 or more and 3 or more attempts at cannulation.

Table 3 compares the groups of patients that required single versus multiple attempts at cannulation. Patients that required multiple attempts were on average younger, had a higher ASA classification, and were more likely to have a history of difficult PIV placement. Table 4 demonstrates provider characteristics and results of intravenous cannulation among the different provider categories. Anesthesia professionals (anesthesiology attending or CRNA) performed the IV cannulation in 67.6% of patients. Trainees placed the PIV in 24.7% of the cases while students established the IV in 7.8%

Table 2 Odds Ratios for Three or More Attempts (DIVA)

Variable	OR (95% CI)
Age (years)	
<1 year	8.73 (3.38, 22.6)
1–3 years	4.93 (2.05, 11.8)
4–5 years	1.71 (0.60, 4.91)
6–9 years	Reference
10–12 years	1.57 (0.47, 5.27)
13–15 years	2.19 (0.60, 8.03)
≥16 years	2.16 (0.52, 8.95)
BMI	0.98 (0.93, 1.02)
Gender	
Male	Reference
Female	0.89 (0.57, 1.39)
Race	
White	Reference
Black or African American	1.33 (0.77, 2.31)
Other	0.42 (0.15, 1.17)
ASA Class	
ASA 1	Reference
ASA 2	1.95 (1.10, 3.46)
ASA 3 and 4	1.97 (0.92, 4.24)
History of difficult IV placement	3.46 (1.70, 7.08)
Patient had an IV within the past week	2.08 (0.45, 9.65)
Provider	
Attending	Reference
CRNA	1.02 (0.52, 1.99)
Trainee	1.42 (0.86, 2.35)
Student	0.60 (0.21, 1.72)
Number of years of experience	0.99 (0.96, 1.03)

Note: Trainee includes fellows and residents; students include medical students and SRNAs.

Abbreviations: BMI, body mass index; OR, odds ratio; CI, confidence interval; IV, intravenous; ASA, American Society of Anesthesiologists; CRNA, Certified Registered Nurse Anesthetist; SRNA, student nurse anesthetist.

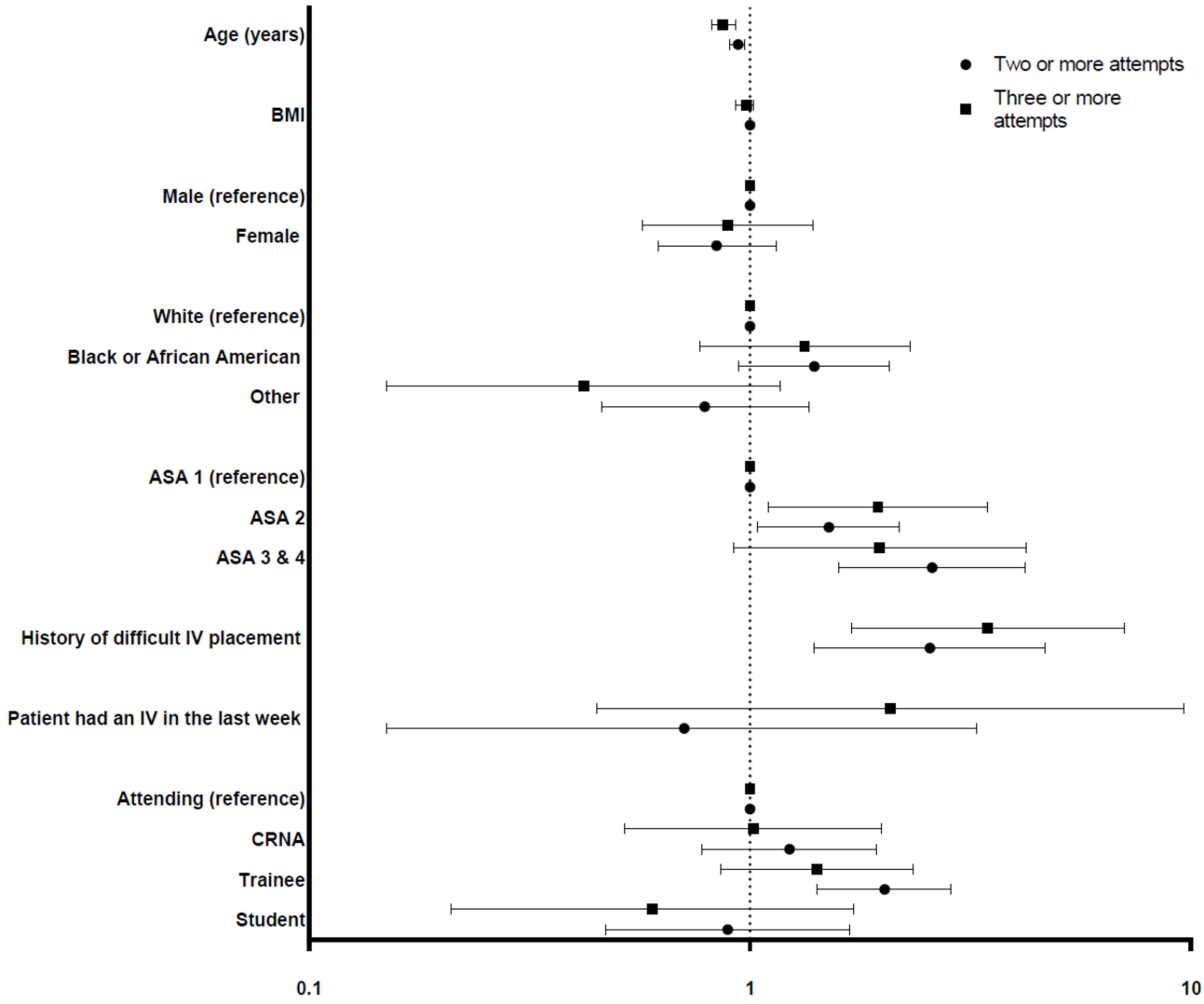

Figure 1 Risk factors with odds ratios for 2 or more (black circles) and 3 or more attempts (black diamonds).

of the cases. Anesthesiologists, CRNAs, trainees, and students had a first attempt success rate of 82%, 78%, 69% and 82%, respectively. Time to successful cannulation was a median of 1.3 minutes for attendings, 1.5 minutes for CRNAs, 1.7 minutes for trainees, and 1.3 minutes for students.

Discussion

The present study represents one of the largest prospective trials examining pediatric intravenous cannulation in the perioperative setting. With an enrollment of over one thousand patients, it provides a broad perspective on the topic given the diversity within the patient population, as well as the spectrum of anesthetizing locations included. While there is lack of consensus regarding the definition of difficult IV access (DIVA), we defined DIVA as patients requiring three or more attempts at cannulation, consistent with previously published trials.[14–16] Using this definition, we found that only 9% of pediatric patients met DIVA criteria, while the majority of subjects (78%) were successfully cannulated on the initial attempt. Patient factors that were associated with DIVA included younger age, higher ASA classification, and prior documented history of difficult PIV placement. Factors such as BMI, gender and race were not significant predictors of DIVA. Similarly, provider class (ie attending anesthesiologist or CRNA versus trainee or student) and timing of placement (ie awake versus anesthetized) were also not significantly associated with DIVA.

Table 3 Comparison of Success Rate with 1 Attempt versus 2 or More Attempts

Variable	1 Attempt (n = 783)	≥ 2 Attempts (n = 219)	p-value
Age	5 (2, 9)	3 (1, 7)	<0.001
Weight	20 (14, 37)	15 (11, 26)	<0.001
Height	113 (93, 138)	100 (80, 121)	<0.001
BMI	17 (15, 20)	17 (16, 20)	0.304
Gender			0.275
Female	347 (44%)	88 (40%)	
Male	436 (56%)	131 (60%)	
Race			0.134
White	585 (75%)	158 (72%)	
Black or African American	114 (15%)	43 (20%)	
Other	84 (11%)	18 (8%)	
ASA			0.002
ASA 1	246 (31%)	47 (21%)	
ASA 2	452 (58%)	130 (59%)	
ASA 3	80 (10%)	450 (18%)	
ASA 4	5 (1%)	2 (1%)	
History of difficult IV placement	28 (4%)	19 (9%)	0.002
Patient had an IV within the past week	10 (1%)	2 (1%)	0.656
Provider			0.001
Attending	436 (56%)	98 (45%)	
CRNA	112 (14%)	31 (14%)	
Anesthesia Trainee	170 (22%)	77 (35%)	
Student Nurse Anesthetists	65 (8%)	13 (6%)	
Years of experience	7 (2, 12)	6 (2, 12)	0.282
How difficult do you anticipate this IV placement will be?[a]	3 (2, 4)	4 (3, 7)	<0.001
How difficult was this IV placement?[a]	2 (1, 3)	5 (3, 7)	<0.001
Time to successful cannulation (minutes)	0.94 (0, 1)	3.2 (2, 4)	<0.001
When was the first cannulation attempted			0.884
After inhalation induction	680 (87%)	194 (89%)	
After nitrous oxide	87 (11%)	21 (10%)	
After midazolam	3 (0.4%)	0	
Awake	13 (1.6%)	4 (1%)	

Notes: Data are reported as the number (%) or median (interquartile range). Trainee includes fellows and residents; Students include medical students and SRNAs. [a]Visual Analogue score from 1–10. p-value: Wilcoxon test, chi square test, Fisher's exact test.

Previous reports have demonstrated similar rates of first attempt success for pediatric patients in the operating room compared to this study. In 2012, a prospective, observational study by Cuper et al reported a 73% first attempt IV success rate for pediatric patients in the operating room,[3] comparable to the first attempt success rate of 78% in this trial. It is clear from some reports that a majority of pediatric patients are successfully cannulated on the first try, but around one-in-four patients will require multiple attempts, which may lead to increased operating room time, undue exposure to anesthetic agents, practitioner frustration, and patient morbidity.[17]

Our finding that age is one of the major determinants of cannulation success rate is also in agreement with previous publications.[3,18] In the present study, the mean age of patients who required a single attempt at cannulation was five years (IQR 2, 9), and the mean age of patients who required more than one attempt was three years (IQR 1, 7). Compared to the reference group of patients between the ages of 6 and 9 years, patients under the age of one and patients between the

Table 4 Provider Role and Cannulation Difficulty

Variable	Attending (n = 534)	CRNA (n = 143)	Trainee[a] (n = 247)	Student (n = 78)	p-value
How difficult do you anticipate this IV placement will be?[b]	3.2 (2, 5)	3.1 (2, 4)	3.8 (2, 5)	3.6 (3, 4)	0.001
How difficult was this IV placement?[c]	2.6 (1, 3)	2.5 (1, 3)	3.1 (2, 4)	2.7 (2, 3)	0.008
Number of attempts					0.011
One	436 (82%)	112 (78%)	170 (69%)	65 (82%)	
Two	54 (10%)	19 (13%)	49 (20%)	9 (12%)	
Three	28 (5%)	6 (4%)	20 (8%)	2 (3%)	
≥ Four	16 (3%)	6 (4%)	8 (3%)	2 (3%)	
Time to successful cannulation (minutes)	1.3 (0, 2)	1.5 (1, 2)	1.7 (1, 2)	1.3 (1, 2)	0.012

Notes: Data are reported as number (%) or mean (interquartile range). [a]Trainee included fellows and residents; students included medical students and student nurse anesthetists. [b]p-value calculated using ANOVA, significance level p <0.05. [c]Visual analogue score from 1–10.
Abbreviations: IV, intravenous; CRNA, Certified Registered Nurse Anesthetist.

ages of one and three years were significantly more likely to be classified as DIVA. Cuper et al also reported in 2012 that younger age was predictive of multiple attempts at cannulation, with first attempt success rate improving progressively with age. For instance, the first attempt success rate reported for neonates and infants was only 53.5%, with noted improvement to nearly 85% for adolescents. Similarly to Cuper's, our study was designed as a prospective cohort, further validating the quality of data collection, and ameliorating the potential effect of confounding variables within our results.

Higher ASA physical status classification was another important factor determined to be predictive of DIVA. This finding correlates with a 2019 retrospective review by Patak et al, which also aimed to characterize difficult PIV access. This effort reviewed data pertaining to 12,314 children undergoing 15,068 anesthetics. They defined difficult PIV as a binary subjective measure (yes or no) based on the attending anesthesiologist's experience. In this review, the difficult IV incidence was 5.3%, and patients classified as difficult PIV placement were more likely to have ASA III (OR 4.25; 95% CI 3.3–5.49) or ASA IV (OR 6.5; 95% CI 4.26–9.92) status.[17] In the present study, patients that were classified as ASA II, as well as patients classified as ASA and IV had significantly higher odds ratio of requiring three or more attempts at cannulation. There are likely multiple reasons why higher ASA status is associated with difficult IV access. For instance, there may be a higher incidence of thrombophlebitis in hospitalized patients resulting from intravenous infusions or multiple prior cannulations,[19] and patients with significant edema, hypovolemia or dehydration are generally considered more difficult to cannulate.[20,21] A survey performed in 2020 among pediatric anesthesiologists and nurse anesthetists aimed to identify specific patient characteristics that are perceived to increase the likelihood of difficult PIV cannulation. Factors most commonly reported included ASA status ≥ IV, trisomy 21, neuromuscular disorders, and history of multiple prior IV cannulations.[22] Unfortunately, there is a dearth of evidence that shows a causal relationship between specific comorbidities and DIVA in pediatric patients.

Remarkably, we did not find BMI to increase the chances of DIVA, as the odds of requiring multiple attempts at cannulation were not noted to be higher in patients with elevated BMI. This is in contrast with findings from previous studies. Generally, obesity and elevated BMI are considered to be associated with difficult peripheral IV access.[18,23,24] This association was further substantiated in the pediatric population by Nafiu et al in 2010.[25] Looking at a study population of 103 (56 lean and 47 obese) pediatric patients, Nafiu and his team determined PIV placement to be more challenging in obese children compared to their lean peers. In fact, Nafiu determined that only 39% of lean patients required multiple attempts, compared to 62% of obese patients. Our study and Nafiu's share similarity in that both were designed as prospective and observational in nature, albeit with some key differences. Nafiu compared patients designated as obese, with a BMI greater than the 95th percentile, to those defined as normal weight, namely patients with a BMI less than the 85th percentile. In our study, we elected to categorize patients based on BMI above or below the 85th percentile. In essence, our study compared obese and overweight children to normal weight children, while Nafiu compared strictly obese children to normal weight children. Including patients with BMI between the 85th and 95th percentile may help explain why BMI as a variable did not reach statistical significance as it relates to DIVA.

Another interesting finding was that success rate did not differ significantly between types of providers. Compared to attending anesthesiologists, no other role of anesthesia provider (ie CRNAs, trainees, and students) was associated with requiring more attempts at cannulation. Data on this topic is conflicting. While some reports seem to support that pediatric anesthetic nurses may experience higher first time success, compared to physician anesthesiologists,[3] others have reported the role of anesthesia provider performing the procedure does not significantly affect success rate.[25] The comparable success rate between anesthesia staff and trainees was unexpected, but it is possible that clinically experienced staff (attending physicians and CRNAs) are generally more compelled to attempt cannulation when veins are perceived to be more difficult upon initial examination.

We also looked at first cannulation success rate in relation to anesthetic induction technique. The vast majority of patients were cannulated following administration of nitrous oxide or after inhalation induction with sevoflurane. There have been several studies conducted to determine optimum time to attempt IV cannulation following inhalational induction in pediatric patients,[26–28] however, none were found that have directly compared success rates of awake versus asleep PIV placement. While inhalational induction with volatile anesthetic is thought to provide optimum cannulating conditions, including lack of patient movement and added peripheral venodilation, we did not find inhalation induction to play a significant role in reducing the odds of multiple PIV attempts.

The findings presented in this study can help guide future clinical practice and research in a number of ways. The patient factors we found to be associated with DIVA may be used to identify potentially difficult patients earlier, prior to coming to the operating room. Such patients may benefit from early intervention such as additional assistance from experienced providers or utilization of ultrasound, which has been shown to improve cannulation success in pediatric patients in both a 2019 randomized controlled trial[29] and a 2021 systemic review and meta-analysis.[30] Further, a pediatric DIVA scoring system similar to ones previously developed[12] could be tailored to patients in the perioperative setting. Resource utilization and hospital costs may improve if we are able to more systematically approach the DIVA patient in the operating room to decrease attempts and time to cannulation, as a recent large, observational trial has shown such outcomes in hospitalized pediatric patients.[30]

There are several limitations to the present study. First, it was conducted at a single institution, and outcomes could vary at other institutions caring for potentially different patient populations, or with different provider and anesthesia staff compositions. Second, this study was designed to be prospective and observational, and not as a randomized controlled trial, thus certain factors such as cannula size, cannulation site, technique of cannulation, aids for cannulation such as ultrasound with predetermined timing of utilization of these resources, and anesthetic induction technique were not standardized. Other patient characteristics, such as medication history, presence of coexisting disease, and history of prematurity, were not specifically examined in this study.

In conclusion, we found that approximately 9% of patients presented with DIVA were defined as requiring three or more attempts at cannulation in the operating room. Patients considered as DIVA were generally younger, had a higher ASA classification, and registered a prior history of difficult IV placement. We also found that BMI, practitioner role, and induction technique during cannulation attempts did not significantly affect success rates.

Disclosure

The authors report no conflicts of interest in this work.

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