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ORIGINAL RESEARCH

A Survey to Define and Predict Difficult Vascular Access in the Pediatric Perioperative Population

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Background: Various criteria exist for defining difficult peripheral intravenous (DPIV) cannulation in infants and children. With the help of a survey tool, the characteristics perceived to increase the likelihood of DPIV cannulation amongst anesthesia providers were assessed.

Methods: An individualized survey regarding DPIV which included pediatric anesthesiology faculty and certified registered nurse anesthetists at Nationwide Children's Hospital and anesthesiology faculty members of Wake-up Safe was conducted. Anesthesia provider, patient, and procedural characteristics were expressed as a count and percentage, and compared according to group (faculty, certified registered nurse anesthetists, Wake-up Safe faculty) using analysis of variance.

Results: Of the 48 local respondents, 33 (69%) reported age as a contributing factor to DPIV, and 32 (67%) reported weight as a factor. Of the 22 Wake-up Safe respondents, 14 (63%) reported age, and 16 (73%) reported weight as a factor. Patient and procedural characteristics perceived to increased likelihood of DPIV cannulation did not differ by respondent role. The factors most commonly mentioned by local respondents as contributing to DPIV included trisomy 21, neuromuscular disorders, and history of many prior IV cannulations. Among the Wake-up Safe faculty respondents, the most commonly mentioned factors were neuromuscular disorders, trisomy 21, and skin injuries or conditions.

Conclusion: Age and weight were the two most commonly reported factors from both groups of respondents. Other factors contributing to DPIV included prior history of DPIV, neuromuscular disorders, trisomy 21 and American Society of Anesthesiology status ≥4. Patient and procedural characteristics were perceived to increase the likelihood of DPIV cannulation with no difference among respondents.

Keywords: peripheral intravenous cannulation, pediatric anesthesiology, difficult peripheral intravenous cannulation

Introduction

The insertion of a peripheral intravenous (IV) cannula is the most common invasive procedure performed in health care settings.[1] Intravenous cannulation is vital to allow for the administration of fluid, medications, contrast agents for imaging, and transfusion of blood and blood products. In all except the simplest and briefest of surgical procedures, placement of a peripheral intravenous cannula is performed following the induction of anesthesia, and prior to the start of the surgical procedure.[2] Nonetheless, obtaining IV access may be challenging even for experienced health-care professionals.[3] In fact, placement of a peripheral intravenous cannula may be one of the more common challenges faced during the provision of anesthesia to infants and children.[4,5]

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In pediatric anesthesia, there are various definitions as to what constitutes difficult placement of an intravenous (DPIV) cannula, and what type of patients or clinical circumstances are particularly challenging. In addition, providers may have various levels of experience as well as expertise with alternative methods for cannulation, such as ultrasound (US) guidance, vein finders, infrared devices, and other adjunctive aids.[6,7] A survey of anesthesia providers at our institution and participating Wake-up Safe (WUS) member faculty was conducted to determine what factors the practitioners felt contributed to DPIV. WUS is a certified patient safety organization that contains a registry of serious adverse events (AEs) reported on a voluntary basis by participating institutions.

Methods

This study was reviewed and approved by the Institutional Review Board of Nationwide Children's Hospital. As a survey study without the involvement of human subjects, a waiver of informed consent and HIPAA authorization was granted. The individualized survey for the study which is outlined in Table 1 was distributed via email to anesthesia providers including pediatric anesthesiology faculty and certified registered nurse anesthetists (CRNA) at Nationwide Children's Hospital (NCH), and anesthesiology faculty members of WUS. WUS is a patient safety organization established in 2008 by the Quality and Safety Committee of the Society for Pediatric Anesthesia that maintains a registry of de-identified, serious AEs associated with children receiving anesthetic care.

The demographic information collected on anesthesia provider characteristics included years in clinical practice, training and experience in US-guided venous cannulation, and number of unsuccessful venous cannulation attempts they would make prior to calling for assistance or using US guidance. Data on patient and procedure characteristics perceived to increase the likelihood of DPIV cannulation including patient age, weight, American Society of Anesthesiologists' (ASA) physical status, and procedure/surgery type was also collected. Respondents also described patient factors contributing to DPIV in free-response fields. The respondents were asked to choose one option for each of the questions listed in the table. Anesthesia provider, patient, and procedural characteristics were expressed as a count and percentage, and compared according to group (faculty, CRNA, WUS) using ANOVA. All statistical analyses

Table 1 Survey on Factors that Affect Difficult Peripheral Intravenous Cannulation

Variables	Choose One of the Following
Patient's age	• Prematurity (<37 weeks estimated gestational age) • Newborn (<1 month since birth) • >1 to 6 months • >6 months to 12 months • >12 months to 3 years • >3 years to 5 years • >5 years, but <10 years • >10 years, but <15 years • >15 years
State the patient's weight if they are premature, newborn, or under two years of age	• ≤1 kg • >1–2 kg • >2–3 kg • >3–4 kg • >4–6 kg • Inapplicable; patient is ≥2 years of age
For patients two years or older, provide their body mass index (BMI) adjusted as a percentile for age	• <50% • 51–75% • >76–95% • 96–98% • >99%
Patient's gender	• Male • Female
Patient's race*	• American Indian or Alaska Native • Asian • Black or African American • Hispanic or Latino • Native Hawaiian or other Pacific Islander • White or Caucasian • Not sure/not applicable
Patient's ethnicity*	• Hispanic • Non-Hispanic • Not sure/not applicable
Other patient characteristics. Check all that apply.	• Trisomy 21 • History of neuromuscular condition • History of congenital heart disease • History of joint or limb condition • History of skin condition • History of multiple or recent cannulations

(*Continued*)

Table 1 (Continued).

Variables	Choose One of the Following
Patient's associated syndromes	• Describe, if any
What other characteristics of the patient or case contributed to difficulty with IV access?	• Describe, if any
Variable	**Choose one of the following**
Please select the type of surgery or field performed intra-abdominal or pelvic surgery during this encounter.	• Intra-abdominal or pelvic surgery • Orthopedic • Neurologic • Plastics • Other surgical specialty/ procedure • Imagining/off-site anesthesia
Please identify your role as anesthesia provider	• Attending physician • CRNA • Resident in anesthesiology • Resident, other specialty • Fellow in pediatric anesthesiology • Fellow, other specialty • Student nurse anesthetist (SRNA)
Clinical experience in your current role (years in practice)?	• 0–5 years • 6–10 years • 11–15 years • >15 years
Select the best option that describes your training in anesthesiology	• 0–5 years • 6–10 years • 11–15 years • >15 years
Regarding US use, how did you acquire your clinical experience? Please select one option.	• Residency/Fellowship academic training • US-guided vascular access workshop • On-the-job training with expert assistance • Self-taught • I have no experience with this technology
How many unsuccessful venous cannulation attempts would you make prior to calling for assistance?	• 0–5 • 6–10 • 11–15 • 16–20 • >20 • Not sure/not applicable
Are you aware of NCH Department of Anesthesia and Pain Management guidelines for number of cannulation attempts prior to calling for assistance?	• Yes • No

(*Continued*)

Table 1 (Continued).

Note: *Race and Ethnicity as defined by "Standards for the classification of Federal Data on Race and Ethnicity," provided by Executive Office of the President, Office of Management and Budget (OMB), Office of Information and Regulatory Affairs.

were completed using SAS 9.4 (SAS Institute, Cary, NC, USA).

Results

Responses were obtained from 62% of local faculty (n=25), 56% of local CRNAs (n=23), and 21% of WUS member faculty (n=22). Anesthesia provider characteristics according to group are summarized in Table 2. Of the 48 local respondents, 42 (88%) stated they would call for assistance or use US after fewer than five unsuccessful IV attempts. Of the 22 WUS respondents, 17 (77%) stated they would call for help or use US guidance after fewer than five unsuccessful attempts, and four (18%) would call for help or use US guidance after 6–10 unsuccessful attempts. Among the 42 local providers and 20 WUS members with US experience, 16 local providers (38%) and 10 WUS members (50%) had received formal training in US, while 25 locals (62%) and 10 WUS members (50%) reported learning US "on-the-job". The remaining eight providers reported no experience with US guidance. Experience with US guidance did not differ according to study group (p=0.572). Local CRNAs generally had less experience than local faculty or WUS member faculty with US guidance (p<0.01).

Patient and procedural characteristics which were felt to contribute to DPIV cannulation are summarized in Table 3. Of the 48 local respondents, 33 (69%) reported age as a factor contributing to DPIV and 32 (67%) reported weight as a factor. Of the 22 WUS respondents, 14 (63%) reported age as a factor and 16 (73%) reported weight as a factor. With respect to the patient's race and ethnicity, amongst the local respondents, 32 (52%) reported black or African American race to contribute to DPIV cannulation; and 28 (45%) did not choose an applicable answer choice from the listed options. WUS respondents reported similar results, with 12 (60%) reporting Black or African

Table 2 Counts and Percentages of Provider Characteristics by Role of Anesthesia Provider, n (%)

Measure[a]	Faculty (n=25)	CRNA (n=23)	WUS (n=22)	*p*-value[b]
Number of unsuccessful attempts before calling for assistance or using US guidance				
0–5	22 (95.7)	20 (95.2)	17 (77.3)	0.417
6–10	0	1 (4.76)	4 (18.2)	
>11	1 (4.35)	0	0 (0)	
Years of experience				
0–5 years	7 (28.0)	13 (56.5)	4 (18.2)	0.001
6–10 years	4 (16.0)	8 (34.8)	7 (31.8)	
≥11 years	14 (56.0)	2 (8.70)	11 (50.0)	
US guidance skill acquisition				
No formal experience with US guidance	3 (12.0)	3 (13.0)	2 (9.09)	0.572
Formal training (academic training or workshop)	7 (28.0)	9 (39.1)	10 (45.5)	
On-the-job training or self-taught	15 (60.0)	11 (47.8)	10 (45.5)	

Notes: [a]Totals may not sum to group size because of missing data or omitted responses. [b]*p*-value for difference across the three groups using analysis of variance.
Abbreviations: ASA, American Society of Anesthesiologists; CRNA, Certified Registered Nurse Anesthetist; PIV, peripheral intravenous; US, ultrasound.

Table 3 Counts and Percentages of Patient and Procedural Characteristics by Role of Anesthesia Provider, n (%)

Measure[a]	Faculty (n=25)	CRNA (n=23)	WUS (n=22)	*p*-value[b]
Patient characteristics perceived to increase likelihood of difficult PIV cannulation				
Patient age[c]				
Premature birth (<37 weeks gestation)	6 (24.0)	12 (52.2)	6 (27.0)	0.209
Newborn to 12 months	9 (36.0)	6 (26.1)	8 (36.4)	
Age is not a factor	9 (36.0)	4 (17.4)	5 (22.7)	
Patient weight				
<1 kg	9 (36.0)	10 (43.5)	8 (36.4)	0.237
1–6 kg	4 (16.0)	9 (39.1)	8 (36.4)	
Weight is not a factor	12 (48.0)	4 (17.4)	4 (18.2)	
Patient ASA status				
1–3	8 (32.0)	4 (17.4)	9 (45.0)	0.229
≥4	12 (48.0)	11 (47.8)	6 (30.0)	
Any ASA number with emergency status	5 (20.0)	8 (34.8)	5 (25.0)	
Procedure characteristics perceived to increase likelihood of difficult PIV cannulation				
Procedure type				
Surgery	16 (64.0)	16 (69.6)	13 (65.0)	0.824
Imaging or off-site anesthesia	7 (28.0)	6 (26.1)	7 (31.8)	
All of my IV placements are easy/I have not encountered a difficult IV yet	2 (8.0)	1 (4.35)	0	

Notes: [a]Totals may not sum to group size because of missing data or omitted responses. [b]*p*-value for difference across the three groups using ANOVA. [c]Responses for "1–3 years", ">10 and <15 years" excluded from comparison (n=3).
Abbreviations: ASA, American Society of Anesthesiologists; CRNA, Certified Registered Nurse Anesthetist; PIV, peripheral intravenous.

American race as a contributing factor and six (30%) not choosing an applicable choice. 56 (91%) of local respondents and 16 (80%) reported patient's ethnicity was not a contributing factor to determine DPIV cannulation. Patient and procedural characteristics perceived to increased likelihood of DPIV cannulation did not differ by respondent role. The factors most commonly mentioned by local respondents as contributing to DPIV included trisomy 21, neuromuscular disorders, and history of many prior IV cannulations. Among WUS respondents,

the most commonly mentioned factors were neuromuscular disorders, trisomy 21, and skin injuries or conditions.

Discussion

Intravenous cannulation is a routine procedure performed in pediatric hospitals to administer fluids and medications. DPIV cannulation poses a challenging scenario health-care professionals may face in a variety of clinical settings and situations. Problems with venous cannulation can potentially lead to delays in the induction of anesthesia, performance of diagnostic procedures, resuscitation measures, and patient management. Furthermore, the additional time consumed in the operating room can potentially delay subsequent cases and increase health-care costs.[8] Multiple punctures can increase the incidence of complications including skin bruising, phlebitis, extravasation, or nerve damage, and increased needle phobia.[9–11] Our clinical experience also suggests it may be a factor in patient and family dissatisfaction, as we have had experiences with parents expressing significant concern over observed puncture sites postprocedure.

Successful venipuncture with a short procedure time and limited number of attempts may be integral in achieving high patient satisfaction and creating a positive perception of the overall care experience. Early detection of the patient at risk for DPIV is necessary to allow the health-care provider to discuss the potential for DPIV cannulation prior to anesthetic induction, to choose alternate routes or to adopt and implement strategies to increase the probability of success such as use of US guidance.[3] Although widely believed that certain patient characteristics, such as high BMI or younger age may increase the incidence of DPIV cannulation, there is a paucity of literature on specific predictive factors for DPIV cannulation in pediatric patients. To help predict which children will be at risk of DPIV, Yen et al developed a scoring tool, called the Difficult Intravenous Access (DIVA) score, using key factors, including degree of palpability and visibility of the veins, history of prematurity, and age of the child. This was a prospective cohort study consisting of 615 children aged 0 to 21 years undergoing intravenous placement by staff nurses in a pediatric emergency department. Yen found that intravenous access on first attempt was achieved in 75% of the children, whereas the probability of success on first attempt was less than 50% in children with a composite DIVA score ≥ 4.[5] Frey et al conducted a study in a tertiary pediatric institution and reported a 44% success rate per stick with PIV placement, and an average procedure time of 20 min (range: 2–90 min) per patient. A similar study indicated a 53% success rate of PIV placement on the first attempt with a 91% success rate within four attempts.[12,13] These studies, as well as the information from the current study, may provide concepts for future quality improvement projects in this area. Moving forward, quality improvement projects aimed to limit the number of attempts or time required to achieve peripheral venous cannulation may include better identification of the number of attempts that should be allowed prior to use of US guidance. Furthermore, we are currently conducting a prospective evaluation in a large cohort of patients to more clearly define patient and provider characteristics associated with DPIV.

One of the more recent changes in practice which may decrease the incidence of DPIV cannulation is the practice of not only allowing, but actually encouraging oral preoperative hydration. Avoidance of dehydration prior to the operating room setting is feasible by the recent reevaluation of nil per os guidelines, actively encouraging clear liquids up to two hours before a procedure. In addition, improved training and education of unit personnel, institution of IV teams, and interventions to reduce pain and anxiety among patients and parents may facilitate the success of IV cannulation.[14]

For the current survey, the respondent group included local faculty and CRNAs from Nationwide Children's Hospital as well as WUS faculty members from institutions across the United States. With regard to provider characteristics, the majority of providers in all groups stated they would call for assistance or use US guidance before five unsuccessful attempts. One limitation of the study is that we did not differentiate regarding the number of attempts in the 0–5 range. Outside of the operating room, it is not uncommon for attempts by a single provider to be limited to two attempts. However, these practices are not universally accepted in the operating room setting as there are frequently two anesthesia providers in a single operating room (MD anesthesia faculty and CRNA, fellow or resident) as well as ready access to additional providers who are covering adjacent operating rooms. As such, the number of attempts was grouped as 0–5.

Patient and procedural characteristics perceived to increase the likelihood of DPIV cannulation did not differ by respondent role and included both young age and high weight. The factors most commonly mentioned by local respondents as contributing to DPIV included trisomy 21, neuromuscular disorders, and history of many prior IV

cannulations. Amongst WUS respondents, the most commonly mentioned factors were neuromuscular disorders, trisomy 21, and skin injuries or conditions. In our institution, when a DPIV scenario has been identified and peripheral venous cannulation has failed despite several attempts, additional expertise can be readily summoned. This includes anesthesia providers with specialized expertise in US guidance for establishing IV access.

The data obtained via this survey provides characteristics of what may constitute DPIV cannulation during the perioperative period, but it is subject to limitations. This tool was initially designed and tested solely on anesthesia providers in a pediatric institution. Therefore, the findings of this survey may not be generalizable to providers or caregivers from other pediatric specialties or clinical environments. With that caveat in mind, this study supports findings from previous reports confirming that there is no single patient characteristic which may predict DPIV cannulation.[8,15] Respondents all opined that age, weight, and ASA physical status were important contributors. Additional research studies are warranted to provide more insight on specific factors that may lead to DPIV cannulation.

Ethics

This study was reviewed and approved by the ethics committee, named the Institutional Review Board at the Nationwide Children's Hospital and the need for informed consent was waived.

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Disclosure

The authors report no conflicts of interest for this work.

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