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Comparing peripheral venous access between obese and normal weight children

OLUBUKOLA O. NAFIU MD FRCA, CONSTANCE BURKE BSN RN, ANDY COWAN FRCA, NARKO TUTUO MD SARAH MACLEAN MD FRCA AND KEVIN K. TREMPER MD PhD

Department of Anesthesiology, University of Michigan, Ann Arbor, MI, USA

Summary

Introduction: Intravenous (i.v.) access is sometimes a difficult, time-consuming, and highly frustrating procedure. Obesity is widely believed to be associated with difficult peripheral intravenous access (PIV) placement. This study examined the relationship between body mass index (BMI) and ease of venous access in children undergoing noncardiac surgical procedures.

Methods: We prospectively collected data on children aged 2–18 years undergoing elective noncardiac surgery at our institution. A trained research assistant (RA) was present for PIV placement in all patients and noted the following: age, gender, ethnicity, weight, height, and BMI. We also collected data on i.v. insertion site, number of attempts, number of operators, and the number of i.v. cannula used. The main outcome variable was success or failure of i.v. placement on first attempt. Sample size calculation indicated a need for 40 obese and 40 control patients.

Results: A total of 103 (56 lean and 47 obese) patients comprised the study population. PIV cannulation was achieved on the first attempt in 55.2% while 39.6% of patients had 2–3 attempts before successful cannulation. Obese children were more likely to have failed attempt at first cannulation than lean controls ($P < 0.001$). Similarly, obese children were more likely to require two or more attempts at cannulation than lean children ($P < 0.001$).

Conclusion: These data indicate that i.v. placement is more difficult in obese children than their lean peers and that the most likely site for successful placement in obese children after a failed attempt on the dorsum of the hand is the volar surface of the hand. Knowledge of potential sites for successful i.v. access could help to improve the success rate for i.v. placement.

Keywords: peripheral intravenous access; obese; difficult i.v. placement; venous cannulation

Correspondence to: Olubukola O. Nafiu, MD, FRCA, Department of Anesthesiology, University of Michigan, Room UH 1H247, Ann Arbor, MI 48109-0048 (email: onafiu@med.umich.edu).

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Introduction

Peripheral intravenous access (PIV) provides an avenue for the administration of fluids and medications and is a fundamental procedure during elective and emergency surgery (1). Ability to establish intravenous (i.v.) access is an essential skill possessed by pediatric anesthesiologists. However, this is sometimes a difficult, time-consuming, and highly frustrating procedure even for the pediatric anesthesiologist. Interestingly although, despite the fact that almost every anesthetic in children requires the establishment of i.v. access, there are very few studies on the subject that are relevant to pediatric anesthesia (2). The vast majority of literature is from nursing and emergency practice journals (3–5). However, many of these studies focused on either the role of the vascular access nurse, comparing catheter size, operator experience (3–5), cost reduction or the reduction of pain (6) associated with the procedure (7). A recent study specifically relevant to pediatric anesthesia only compared different designs of i.v. catheters but did not specifically address patient factors that may contribute to difficult PIV placement (2).

Obesity is widely believed to be associated with difficult i.v. access (8,9). However, very little robust data exist to substantiate these assumptions. A prospective observational study of adult patients concluded that i.v. insertion was more difficult in morbidly obese than lean adults presenting for routine surgery (10). To date, there are no comparative data in children although clinical experience and general belief suggest that a similar relationship exists between difficult i.v. and body mass index (BMI) in children. With the increasing prevalence of childhood overweight and obesity in the general (11), as well as the pediatric surgical population (12), it may be of value to determine the role of obesity in difficult i.v. access. The objective of this prospective observational study was to examine the relationship between BMI and ease of venous access in children undergoing noncardiac surgical procedures at our institution. We also examined patient and operator factors that may affect successful i.v. cannulation. Our *a priori* hypothesis was that peripheral venous access is more difficult in obese than in nonobese children.

Methods

Following institutional review board approval and waiver of informed consent (no patient care interventions were mandated by this observational study), we prospectively collected data on children aged 2–18 years presenting for elective noncardiac surgery at the Mott Children's Hospital, University of Michigan. Patients were excluded from the study whether they had any of these exclusion criteria: hypovolemic shock, cardiac surgery, chronic steroid therapy, children on chemotherapy, or i.v. fluid therapy within the preceding 7 days as well as recent neonatal intensive care unit (NICU) graduates.

A RA was present in the operating room for i.v. placement in all patients and noted the following: age, gender, ethnicity, body weight, and height. BMI was calculated as weight in kilograms divided by the square of the height in meters (BMI = $kg{\cdot}m^{-2}$). Children were classified as normal weight (BMI < 85th percentile) or obese (BMI ≥ 95th percentile) using age and gender-specific reference growth charts from the National Center for Health Statistics (NCHS)/Centers for Disease Control and Prevention (CDC) (13).

We also collected data on i.v. insertion site, whether veins were visible or palpable prior to cannulation, number of attempts, number of operators, and the number of i.v. cannula used. The main outcome variable was success or failure of i.v. placement on first attempt. We computed 'induction-to-i.v. time' as the time from the onset of inhalational induction to the successful placement of i.v.

Following induction of general anesthesia, a tourniquet was applied to the proximal part of the limb chosen for i.v. insertion site and aseptic skin preparation performed in the standard manner. We recorded an 'i.v. cannulation time' as the time from the application of tourniquet to successful vein cannulation. Intravenous insertion site was documented as follows: dorsal hand, volar hand, forearm, ante-cubital fossa, foot, or other. Operator grade (trainee, nurse anesthetist, Attending) was noted. The size of peripheral cannula used was noted as well as the number of attempts at peripheral venous cannulation. An attempt was defined as skin puncture with the chosen cannula

with or without evidence of intravascular entry (blood flashback). Successful i.v. placement was defined as blood flashback into the hub of the catheter as well as ability to freely infuse fluids through the catheter. Unsuccessful attempt was defined as skin puncture without blood flashback or resistance to i.v. fluid infusion with or without swelling at the insertion site. We also noted the number of additional operators involved in securing the i.v. access. An operator was defined as any caregiver that attempts to place an i.v. and punctures the skin. The operator(s) were asked whether the vein was visible or palpable before they attempted i.v. placement (visibility or palpability). The number of peripheral catheters used on each patient before successful i.v. placement was recorded.

Statistical analysis

Data analysis was performed with SPSS® v.16.0 for Windows (SPSS Inc. Chicago, IL, USA). The primary outcome variable was success or failure of peripheral i.v. placement on first attempt between normal weight and obese children. Means and standard deviations of age and anthropometric variables were computed and compared along BMI categories. Frequency of categorical variables like number of i.v. attempts and caliber and type of i.v. catheter used are expressed as percentages. The mean number of i.v. attempts before success was compared between the BMI categories. We also assessed the correlation between BMI and the gauge of i.v. catheter used on each patient.

Sample size calculation

Because of the lack of data on the subject of difficult i.v. between obese and lean children in the literature, we carried out a pilot study on 40 (20 normal weight and 20 obese) patients. From this pilot data, we determined that when the sample size in each of the groups is 40, a one-way analysis of variance will have 80% power to detect at the 0.05 level a true difference in need for more than one attempt at PIV cannulation between obese and lean children. We, however, recruited more patients than this in anticipation of possible attrition or incomplete data.

Results

A total of 103 (56 lean and 47 obese) patients comprised the study population. Obese patients were slightly older than lean patients (9.7 ± 4.5 years vs 7.8 ± 4.6 years; $P = 0.04$). Apart from the expected difference in BMI, the other demographic parameters were comparable between the two groups (Table 1). Young children (aged ≤4 years) comprised 27.1% of the study population. Anesthesia professionals (faculty or nurse anesthetists) performed the i.v. cannulation in 62.5% of patients while the remaining i.v. was established by trainees. i.v. cannulation was achieved on the first attempt in 55.2% while 39.6% of patients had 2–3 attempts before successful cannulation. There was no significant difference in the failure rate at first attempt between trainees and staff (46.7% vs 41.7%; $P = 0.67$). The overall 'induction to i.v. time' was 3.2 ± 2.5 min. There was no significant difference in the 'induction to i.v. time' between obese and lean patients (3.6 ± 2.8 min vs 3.0 ± 2.5 min; $P = 0.83$). However, the 'i.v. cannulation time' was significantly longer in obese than in lean patients (Table 1).

Table 1
Baseline patient characteristics and results of intravenous cannulation between obese and lean children

	Mean (SD) or %		
Group	*Obese* (N = 47)	*Lean controls* (N = 56)	P-*value*
Age (year)	9.7 (4.5)	7.8 (4.6)	0.04
BMI ($kg \cdot m^{-2}$)	29.6 (3.4)	17.3 (5.6)	0.001
Males	51.6	48.4	0.62
Non-white race	14	14	0.54
ASA class	1.8 (0.4)	1.2 (0.6)	ns
NPO duration (h)	5.9 (2.7)	7.0 (2.5)	0.03
Vein visible	39.5	60.5	0.001
Vein palpable	36.5	63.5	0.001
Intravenous cannulation time (s)	187.8 (114.8)	130.1(112.0)	0.03
Successful cannulation			
First attempt	40.8	59.2	0.017
≥2	61.8	38.7	0.005
Intravenous site			
Dorsum of hand	67.1	87.2	0.03
Forearm	5.4	8.5	0.81
Volar surface	25.0	2.1	0.03

All *P*-values generated with Pearson chi square.
BMI, body mass index; NPO, nil per os; ASA, American Society of Anesthesiologists.

BMI showed a slight negative correlation with the gauge of i.v. cannula used ($r = -0.31$, $P = 0.03$) indicating that operators tended to choose smaller gauge cannula for children with high BMI. Correspondingly, lean patients were more likely to have visible or palpable veins than their obese peers (Table 1). Obese children were more likely to have failed attempt at first cannulation than lean controls. Similarly, obese children were more likely to require two or more attempts at cannulation than lean children ($P \leq 0.01$, Table 1). Correspondingly, obese children required more than one new i.v. catheters for successful i.v. placement than their lean peers (54.2% vs 20.8%; $\chi^2 = 10.34$, $P = 0.001$) indicating that obese children consumed more i.v.-related resources. The most popular site for i.v. cannulation was the dorsum of the hand in both obese and lean patients. After a failed first attempt on the dorsum of the hand, the next likely place for success was the volar surface of the wrist where a significantly higher success rate was achieved in obese than in lean patients (20.8% vs 2.1%; $P = 0.03$, Table 1).

Discussion

In this prospective, observational study, we have shown that i.v. placement is more difficult in obese children than their lean peers. We also found that the most likely site for successful placement in obese children after a failed attempt on the dorsum of the hand is the volar surface of the wrist.

Almost every anesthetic or surgical procedure in children requires the establishment of an i.v. line. In the majority of cases this is a simple procedure, requiring only one attempt. However, i.v. can be a challenging, frustrating, and time-consuming procedure even for the experienced practitioner. Several factors determine the likelihood of success at PIV placement; these include operator experience, cannula size, ambient lighting as well as patient factors like age, skin tone, and obesity.

Obesity is widely believed to be associated with difficult i.v. access (8,9). However, very little data exist to substantiate this assumption. A prospective study of 56 adult patients concluded that i.v. insertion was more difficult in morbidly obese than lean adults presenting for routine surgery (10). We provide the first pediatric data that supports this observation. The thicker subcutaneous adipose tissue layer in obese patients could explain the lower success rate and multiple attempts at i.v. insertion in obese patients. Superficial veins are located in the subcutaneous tissue (14), and a thick adipose tissue layer could obscure visibility and palpability of these veins. These two factors have been previously shown to affect success in vein cannulation in children (15).

Our data suggest that operators prefer the dorsum of the hand for i.v. access in both groups of children. However, there was a higher chance of success on the volar surface of the wrist on second attempt in obese than in lean patients. This could be of clinical relevance because *a priori* identification of potential sites of successful cannulation could reduce the time spent and the number of attempts at venous cannulation. It is not clear why veins on the volar surface of the wrist were easier to cannulate in obese than in lean patients. However, one possible explanation is that the volar surface contains mostly the short and long tendons of the forearm and hand muscles as well as the flexor retinaculum (16). It is possible that these tendons preclude adipose tissue deposition on the volar surface of the hand, which will make the volar veins easier to see and cannulate.

We were somewhat surprised that there was no significant difference between trainees and staff in the failure rate at first attempt at i.v. cannulation. This observation is not in agreement with most publications in nursing and emergency department journals (3,5), but is consistent with an earlier report, which showed that trainees were better than Attendings with a new design of i.v. catheter in children under anesthesia (2). It is possible that staff anesthesiologists were more likely to give trainees the opportunity to attempt i.v. placement when there are multiple prominent veins than when easy venous access is less certain. This would mean that staff anesthesiologists attempted the more difficult i.v. cannulation. It is, however, difficult to assess the likelihood of this happening from an observational study.

Our finding that i.v. access can be difficult even for experienced personnel is consistent with previous reports. An earlier study of practitioners with different levels of experience at i.v. cannulation (3) reported success rates that varied from 44% to 50% in nonsedated children. Other studies with much higher success rates than ours in the emergency

department setting (15) or by i.v. nurse specialists (17) did not specifically compare obese and lean children. Being able to prospectively identify that children are going to require more than one attempt at i.v. cannulation may allow practitioners to give parents an estimate of how many attempts will likely be needed for success. It may also help to determine, which children would benefit from further interventions like ultrasound-guided cannulation and transillumination.

Study limitations

This is a single institution study and centers with dissimilar patient demographics may observe different outcome. Additionally, we did not control for ambient lighting in the operating rooms, which could have affected vein visibility. Similarly, it was impossible to control for operator handicaps like visual acuity or hand tremors. Although these factors may potentially affect an operator's ability to cannulate a vein, we have no reason to believe that they will vary based on a patient's BMI.

Conclusion

We have shown that i.v. placement is more difficult in obese children than their lean peers and that the most likely site for successful placement in obese children after a failed attempt on the dorsum of the hand is the volar surface of the wrist. The need for multiple attempts at i.v. cannulation can delay therapy and can be a source of frustration to the anesthesia personnel and has the potential to distract the caregiver from patient monitoring. Clinicians may consider using the volar surface of the wrist as first choice for i.v. attempt in obese children.

Disclosure

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