Ultrasound guidance versus transillumination for peripheral intravenous cannulation in pediatric patients with difficult venous access

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Objective

Venous access can be technically difficult in pediatric patients because of the small size and impalpability of their veins. The aim of this prospective randomized study was to compare the use of ultrasound (US) guidance and transillumination as aids to facilitate peripheral intravenous cannulation in pediatric patients with difficult venous access.

Patients and methods

We included 80 children, less than 6 years of age, undergoing elective surgery, and having difficult venous access as predicted by a Difficult Intravenous Access score of at least 4. The patients were randomized to either US guidance (the US group, $n = 40$) or transillumination using the Veinlite EMS (the Veinlite group, $n = 40$). Cannulation was performed after inhalation induction of anesthesia. The primary outcome measure was the first-attempt success rate of cannulation. The secondary outcome measures were the overall success rate of cannulation, number of attempts, and time required to achieve successful cannulation.

Results

The first-attempt success rate was significantly higher in the US group (82.5%) compared with the Veinlite group (57.5%, $P < 0.05$). Both groups showed a high overall success rate (92.5% in the US group and 80% in the Veinlite group, $P = 0.19$). The time to achieve successful cannulation was significantly shorter in the US group (67.1 ± 19.3 s) than in the Veinlite group (94.1 ± 49.9 s, $P < 0.01$). The number of attempts required was not significantly different between the two groups.

Conclusion

Both US guidance and transillumination facilitate peripheral intravenous cannulation in pediatric patients with difficult venous access, resulting in a high overall success rate of cannulation. US guidance is superior as it results in a higher first-attempt success rate with less time required to achieve successful cannulation compared with transillumination.

Keywords:
difficult venous access, pediatric peripheral intravenous cannulation, transillumination, ultrasound guidance

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Introduction

Acquiring venous access in infants and young children can be very challenging and time consuming even for the most skilled hands. In this age group, veins are very small and embedded in a thick layer of subcutaneous fat, which make them less palpable and visible. Numerous previous venipunctures add significantly to the difficulty of cannulations. Failure to perform peripheral intravenous cannulation (PIVC) of a child during induction of anesthesia may necessitate alternative solutions such as central venous cannulation or a venous cutdown. These alternatives are more time consuming and carry a higher risk of complications [1,2].

Ultrasound (US) guidance has been proved to increase the success rate of central venous cannulation in both adults [3] and pediatrics [4]. More recently, US guidance has also been used during PIVC in adults [5–7]. The use of US was found to result in a faster access with fewer insertion attempts and decreased incidence of complications compared with traditional cannulation techniques [7]. Similar studies performed in the pediatric age group have also shown very encouraging results [8,9].

The first use of transillumination to facilitate venous access dates back to 1975 [10]. However, its use in anesthesia practice is still uncommon. It depends on the use of a high-powered, cold source of light to illuminate subcutaneous tissues. Deoxygenated blood in veins absorbs the light; hence, veins are seen as dark lines within the illuminated area. Previous studies using this technique in children with difficult venous access showed a high success rate of PIVC [11,12]. Veinlite, the transillumination device used in our study, was previously tried and found to facilitate PIVC in pediatric patients compared with the traditional cannulation technique [13].

The objective of this prospective randomized study was to compare the efficacy of US guidance and transillumination techniques in facilitating PIVC in pediatric patients with difficult venous access.

Patients and methods

This study was conducted during the period from January 2013 to August 2013 at the Cairo University Specialized Children's Hospital. After approval from the research ethics committee and obtaining written informed consent of the guardians, we included 80 children, less than 6 years of age, with an ASA physical status I or II, undergoing elective surgery, and having difficult venous access. We evaluated the potential for difficult venous access using the Difficult Intravenous Access (DIVA) score (Table 1) [14]. This score is well validated in pediatric patients [15,16]. Patients with a DIVA score of at least 4 have more than 50% likelihood of failed cannulation on the first attempt [15]. Patients were included in this study only if they had a DIVA score of at least 4. Exclusion criteria were hemodynamic instability, need for emergency surgery, and parental refusal.

Before induction of anesthesia, the patients were randomly assigned, using sealed envelopes containing computer-generated random numbers, to one of the two groups: the US group (n = 40) and the Veinlite group (n = 40). All children were cannulated after being anesthetized using inhalation induction with sevoflurane by face mask. All cannulations were performed by the same anesthesiologist, with more than 10 years experience in pediatric anesthesia and more than 1 year experience in using US guidance and Veinlite transillumination as aids for PIVC. Cannulation was performed using the same type of intravenous cannula (BD Venflon; Becton Dickinson, Helsingborg, Sweden) in all patients. Either a 22- or a 24-G cannula was used according to the discretion of the managing anesthesiologist. Preparations for PIVC were performed as usual in both groups; the arm or the leg was positioned hanging downward; a tourniquet was applied above the puncture site; and skin was disinfected using alcohol.

Table 1 Difficult Intravenous Access (DIVA) score [14]

Variables	Score
Veins not visible after tourniquet	2
Veins not palpable after tourniquet	2
Age: <1 year/1–2 years	3/1
History of prematurity	3

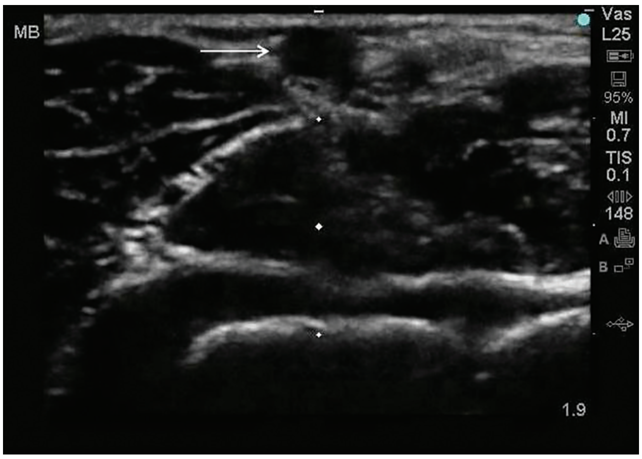
The sum of point values of the variables is the DIVA score (range 0–10).

In the US group, the veins were visualized using a 25-mm 6–13 MHz high-frequency linear transducer (Sonosite M-Turbo; Sonosite Inc., Bothell, Washington, USA). Real-time US-guided cannulation was performed using a short-axis view to visualize veins in cross-section (Fig. 1) and an out-of-plane approach to cannulate the vein. Veins were identified by being compressible with mild probe pressure. A dual-operator technique was used during cannulation. Another physician performed the ultrasonography and centered the vein in the middle of the screen, whereas the managing anesthesiologist advanced the cannula into the vein using a free-hand method (Fig. 2).

In the Veinlite group, the veins were visualized using a Veinlite EMS (TransLite, Sugar Land, Texas, USA), which is a portable transilluminator that uses a patented side-transillumination method to visualize veins. When the Veinlite ring is placed on the skin, a ring of bright fiberoptic light is directed at an angle into the skin and focused under the skin (Fig. 3). This light uniformly illuminates the small region of skin and subcutaneous tissue within the open area of the C-shaped ring without areas of shadow. This shadow-free side-transillumination technique allows for better visualization of veins [13].

The primary outcome measure was the first-attempt success rate, which was defined as successful cannulation achieved at the first attempt. Successful cannulation was confirmed by a 10 ml normal saline flush with

Figure 1



Ultrasonographic image of the basilic vein (white arrow) in a short-axis view scanned at the antecubital fossa.

no signs of infiltration or hematoma formation. An attempt was defined as each puncture of the skin with the needle. Redirection of the needle tip while under the skin was not considered a separate attempt.

The secondary outcome measures included the time to successful cannulation, overall success rate of cannulation, and the number of attempts required to achieve successful cannulation. Time to successful cannulation started when the anesthesiologist started examining the patient for a suitable vein for cannulation and ended when normal saline solution was flushed through the intravenous cannula. Overall success of cannulation was defined as successful cannulation within four attempts. If cannulation was unsuccessful after four attempts, the intervention was considered to have failed. The decision whether to continue cannulation attempts or perform central venous cannulation or a venous cutdown was left to the discretion of the managing anesthesiologist.

The size of the inserted cannula (22 or 24 G) as well as the site of cannulation (upper limb or lower limb) were recorded in all patients who were successfully cannulated. Any incidence of arterial puncture was also reported in the two groups.

Statistical analysis

Using α and β errors of 0.05 and 0.2, respectively, a total sample size of 80 patients, equally allocated into two groups (40 patients per group), had a statistical power of 80% to detect an assumed difference of 30% or more between the first-attempt success rates in the two groups. Statistical analysis was performed using computer programs Microsoft Office Excel 2010 (Microsoft Corporation, New York, USA) and SPSS 16.0 (SPSS Inc., Chicago, Illinois, USA). Data are presented as mean ± SD, median (range), and number (percentage) as appropriate. Categorical data were compared using the Fisher exact test. Continuous data were compared using the Student t-test. Ordinal data were compared using the Mann–Whitney U-test. P value less than 0.05 was considered statistically significant.

Results

The study included 80 children (40 children in the US group and 40 children in the Veinlite group). Table 2 shows the demographic data of both groups. There was no significant difference between the two groups with respect to age, sex distribution, height, weight, BMI, or ASA physical status. The DIVA scores recorded in the two groups were also comparable.

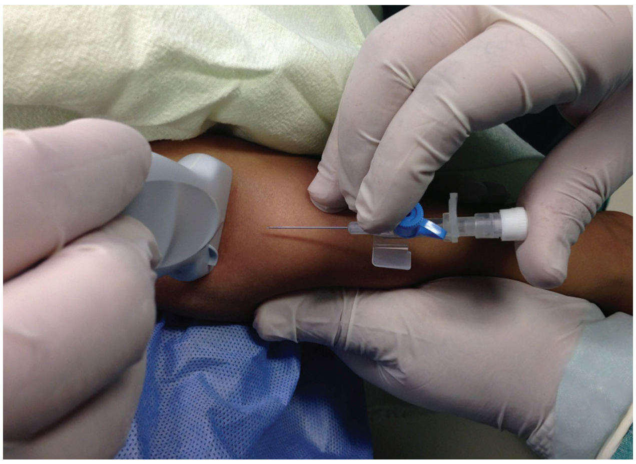
The US group showed a significantly higher first-attempt success rate [33/40 (82.5%) patients] compared with the Veinlite group [23/40 (57.5%) patients, $P < 0.05$]. The overall success rate of cannulation was also higher in the US group [37/40 (92.5%) patients] than in the Veinlite group [32/40 (80%) patients], but this difference did not reach statistical significance (Table 3).

Table 2 Demographic data

Variable	US (n = 40)	Veinlite (n = 40)	P value
Age (months)	19.8 ± 13.8	18.4 ± 11.2	0.62
Sex (male/female)	24/16	21/19	0.65
Weight (kg)	11.9 ± 2.9	11.6 ± 2.5	0.65
Height (cm)	81.3 ± 11.2	79.9 ± 11.0	0.58
BMI (kg/m^2)	17.8 ± 1.9	18.1 ± 1.7	0.47
ASA physical status (I, II)	23/7	26/4	0.51

Values are expressed as mean ± SD or number of patients; ASA, American Society of Anesthesiologists; US, ultrasound.

Figure 2



Dual-operator technique during ultrasound-guided peripheral intravenous cannulation.

Figure 3

Veinlite EMS side-transillumination method to visualize veins.

Table 3 Cannulation data

Variable	US (n = 40)	Veinlite (n = 40)	P value
DIVA score	5.6 ± 1.3	5.8 ± 1.4	0.52
Success on first attempt	33/40 (82.5)	23/40 (57.5)	0.03*
Success on 2–4 attempts	4/40 (10)	9/40 (22.5)	0.22
Overall success rate	37/40 (92.5)	32/40 (80)	0.19
Number of required attempts	1 (1–3)	1 (1–4)	0.17
Time to successful cannulation (s)	67.1 ± 19.3	94.1 ± 49.9	0.007*
Size of cannula used for successful cannulation			0.72
22 G	33/37 (89.2)	27/32 (84.4)	
24 G	4/37 (10.8)	5/32 (15.6)	
Site of successful cannulation			0.74
Upper limb	31/37 (83.8)	28/32 (87.5)	
Lower limb	6/37 (16.2)	4/32 (12.5)	
Incidence of arterial puncture	0	0	1.00

Values are expressed as mean ± SD, median (range), or n (%) of patients; DIVA score, Difficult Intravenous Access score; US, ultrasound; *P < 0.05 designates a statistically significant difference.

The time to successful cannulation was significantly less in the US group (67.1 ± 19.3 s) compared with the Veinlite group (94.1 ± 49.9 s, P < 0.01). The difference in the number of cannulation attempts required in the two groups was not statistically significant (Table 3).

Of the 37 successful cannulations performed in the US group, 33 (89.2%) were performed using a 22-G cannula and four (10.8%) using a 24-G cannula. However, in the Veinlite group, of the 32 successful cannulations performed, 27 (84.4%) were performed using a 22-G cannula and five (15.6%) using a 24-G cannula. Cannulation was performed in the upper limb in 31 (83.8%) patients in the US group and in 28 (87.5%) patients in the Veinlite group. All these differences were not statistically significant (Table 3). There were no incidences of arterial puncture in either group.

Discussion

The present study demonstrated that using either US guidance or Veinlite transillumination during PIVC in children with difficult venous access results in a high success rate of venous cannulation. However, the use of US guidance was associated with a higher first-attempt success rate than the use of transillumination. The time to achieve successful cannulation was also significantly less with the use of US compared with the use of transillumination.

PIVC depends on palpation and/or visualization of target veins. This may not be possible in children because they have smaller veins and increased subcutaneous fat. Numerous previous cannulations in a child add significantly to the difficulty of PIVC. In previous studies, the first-attempt success rate of PIVC in pediatric patients has been shown to be as low as 46% in one study [17] and 48% in another study [18]. Both of these studies were performed on a general pediatric population, whereas in our study we only included children with predicted difficult venous access. Therefore, the high success rates of PIVC that we achieved in our study using US guidance and transillumination (92.5 and 80%. respectively) clearly show that both of these techniques increase the likelihood of successful intravenous placement in children.

Our results are in agreement with several previous studies on the use of US guidance for PIVC in children. Doniger *et al.* [8] performed a randomized controlled trial on 50 children younger than 10 years of age. They found that the success rate of US-guided PIVC was 80% compared with 64% when using traditional attempts. They also found that US-guided PIVC required significantly less time, fewer attempts, and fewer needle redirections than traditional approaches. Benkhadra *et al.* [9] also performed a prospective randomized study on 40 children less than 3 years old with difficult venous access. They found that US guidance significantly increased the first-attempt success rate (85 vs. 35% using traditional approach) and decreased the time and number of attempts required to achieve successful cannulation.

In contrast with our results, Bair *et al.* [19] found that the use of US guidance did not result in a significant difference in cannulation success compared with the standard technique, and they reported a first-attempt success rate of only 35% when using US. This may be due to the fact that they used a 'static' US technique in which they visualized the vein using US and marked the skin overlying the vein with a pen tip. The nurses then immediately used this skin impression as a landmark for cannulation attempts. In our study, we used real-time US guidance, which allows real-time visualization of the vessel during cannulation. This may explain the higher success rate in our study compared with Bair and colleagues.

Previous reports on the use of transillumination to aid PIVC in pediatrics have shown very positive results. In agreement with our results, Atalay *et al.* [12] reported a success rate of 80% with the use of transillumination during PIVC in 100 children less than 3 years of age with difficult venous access. They used a 200-W cold-light source with its fiberoptic cable, which they placed against the palmar or plantar surface of the hand or foot. Goren *et al.* [11] used an otoscope as the source of light for transillumination in 100 children who had no visible veins under normal lighting conditions. By the use of transillumination, they were able to visualize a vein in 40 of these patients, and cannulation was successful in all 40 patients. The only previous study conducted specifically on Veinlite transillumination in pediatric patients was performed by Katsogridakis *et al.* [13]. They performed a randomized controlled trial on 240 pediatric patients and found that the use of Veinlite during PIVC was associated with a success rate of 85%, and that PIVC was 2.1 times more likely to be successful in the first attempt with the use of the device.

We are not aware of any previous studies comparing the use of US guidance and transillumination during PIVC in pediatric patients. Although our results showed that both techniques resulted in a high overall success rate, the use of US guidance had the clear advantage of a higher first-attempt success rate in significantly less time compared with the use of transillumination. This makes the use of US guidance more favorable, especially when cannulation is performed during induction of anesthesia. In children, because of their natural fear for needles, anesthesia is most commonly induced by inhalation through face mask. Any delay in PIVC results in prolonging of the induction time, which may expose the child to risks for hypotension and laryngospasm.

The majority of patients in the two groups were cannulated using a 22-G-sized cannula with only few patients requiring a 24-G cannula because of the very small size of the targeted vein. The fact that the managing anesthesiologist chose a larger bore cannula in most of the patients is another proof that the used techniques facilitated PIVC. Most of the patients in the Veinlite group were cannulated in the dorsum of the hand, whereas most of the patients in the US group were cannulated in the antecubital fossa. This was because these locations provided the best visualization in the two groups. Recently, US-guided cannulation of the great saphenous vein at the ankle level in infants has been tried and found to result in a very high success rate [20].

This study has several limitations. First, as we were using two completely different techniques, blinding was not possible. Second, we excluded children who were hemodynamically unstable as well as those requiring emergency PIVC during emergency surgery. The medical condition of these two groups of pediatric patients may make PIVC even more challenging, which might impact the success rate of the studied techniques. Third, the study was performed in a specialized pediatric hospital, with all the cannulations performed by an anesthesiologist with high experience in pediatric anesthesia and pediatric venous access. Further studies are needed to assess the benefit of using both techniques in settings where pediatric PIVC is less commonly performed. It is in these settings that the aid provided by these two techniques is actually more needed. The anesthesiologist performing the cannulations was also experienced in the use of both US guidance and transillumination as PIVC techniques. It is difficult to predict which technique would be more useful if used by inexperienced hands. Although the use of US reveals the vein in a clearer way, it does have a learning curve. An absolute beginner might find it significantly hard to use during peripheral cannulation. In contrast, transillumination, although less illustrative of the vein, is simpler to use and requires very minimal training.

Conclusion

The use of either US guidance or transillumination allows for a high success rate of PIVC in pediatric patients with difficult venous access. We found the use of US guidance to be superior to transillumination because it was associated with a higher first-attempt success rate and shorter time to achieve successful cannulation, which makes it a useful aid for cannulation during inhalation induction of anesthesia.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

1 Costello JM, Clapper TC, Wypij D. Minimizing complications associated with percutaneous central venous catheter placement in children: recent advances. Pediatr Crit Care Med 2013; 14:273–283.

2 Chappell S, Vilke GM, Chan TC, Harrigan RA, Ufberg JW. Peripheral venous cutdown. J Emerg Med 2006; 31:411–416.

3 Hind D, Calvert N, McWilliams R, Davidson A, Paisley S, Beverley C, *et al.* Ultrasonic locating devices for central venous cannulation: meta-analysis. BMJ 2003; 327:361–367.

4 Leyvi G, Taylor D, Reith E, Wasnick JD. Utility of ultrasound-guided central venous cannulation in pediatric surgical patients: a clinical series. Paediatr Anaesth 2005; 15:953–958.

5 Keyes L, Frazee B, Snoey E, Simon BC, Christy D. Ultrasound-guided brachial and basilic vein cannulation in emergency department patients with difficult intravenous access. Ann Emerg Med 1999; 34:711–714.

6 Brannam L, Blaivas M, Lyon M, Flake M. Emergency nurses' utilization of ultrasound guidance for placement of peripheral intravenous lines in difficult-access patients. Acad Emerg Med. 2004; 11:1361–1363.

7 Costantino TG, Parikh AK, Satz WA, Fojtik JP. Ultrasonography-guided peripheral intravenous access versus traditional approaches in patients with difficult intravenous access. Ann Emerg Med 2005; 46:456–461.

8 Doniger SJ, Ishimine P, Fox JC, Kanegaye JT. Randomized controlled trial of ultrasound guided peripheral intravenous catheter placement versus traditional techniques in difficult-access pediatric patients. Pediatr Emerg Care 2009; 25:154–159.

9 Benkhadra M, Collignon M, Fournel I, Oeuvrard C, Rollin P, Perrin M, *et al.* Ultrasound guidance allows faster peripheral IV cannulation in children under 3 years of age with difficult venous access: a prospective randomized study. Paediatr Anaesth 2012; 22:449–454.

10 Kuhns LR, Martin AJ, Gildersleeve S, Poznanski AK. Intense transillumination for infant venipuncture. Radiology 1975; 116:734–735.

11 Goren A, Laufer J, Yativ N, Kuint J, Ben Ackon M, Rubinshtein M, *et al.* Transillumination of the palm for venipuncture in infants. Pediatr Emerg Care 2001; 17:130–131.

12 Atalay H, Erbay H, Tomatir E, Serin S, Oner O. The use of transillumination for peripheral venous access in paediatric anaesthesia. Eur J Anaesthesiol 2005; 22:317–318.

13 Katsogridakis YL, Seshadri R, Sullivan C, Waltzman ML. Veinlite transillumination in the pediatric emergency department: a therapeutic interventional trial. Pediatr Emerg Care 2008; 24:83–88.

14 Yen K, Riegert A, Gorelick MH. Derivation of the DIVA Score: a clinical prediction rule for the identification of children with difficult intravenous access. Pediatr Emerg Care 2008; 24:143–147.

15 Riker MW, Kennedy C, Winfrey BS, Yen K, Dowd MD. Validation and refinement of the difficult intravenous access score: a clinical prediction rule for identifying children with difficult intravenous access. Acad Emerg Med 2011; 18:1129–1134.

16 O'Neill MB, Dillane M, Hanipah NF. Validating the difficult intravenous access clinical prediction rule. Pediatr Emerg Care 2012; 28:1314–1316.

17 Larsen P, Eldridge D, Brinkley J, Newton D, Goff D, Hartzog T, *et al.* Pediatric peripheral intravenous access: does nursing experience and competence really make a difference? J Infus Nurs 2010; 33:226–235.

18 Reigart JR, Chamberlain KH, Eldridge D, O'Brien ES, Freeland KD, Larsen P, *et al.* Peripheral intravenous access in pediatric inpatients. Clin Pediatr 2012; 51:468–472.

19 Bair AE, Rose JS, Vance CW, Andrada-Brown E, Kuppermann N. Ultrasound-assisted peripheral venous access in young children: a randomized controlled trial and pilot feasibility study. West J Emerg Med 2008; 9:219–224.

20 Jumani DB, Murphy P. Ultrasound-guided cannulation of the great saphenous vein at the ankle in infants. Br J Anaesth 2012; 109:129–130.