DOI: https://doi.org/10.5114/ait.2021.103515

Infrared vein visualisation devices for ease of intravenous access in children: hope versus hype

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Abstract
Peripheral intravenous placement can be difficult in children. Vein finder devices are vascular access devices that delineate veins lying in the subcutaneous tissues to identify potential venipuncture sites. In this narrative review, we highlight the currently available literature on this device to analyse the hope that this device has to offer vs. the unnecessary hype. The search of the databases (Cochrane Library, Google Scholar, and PubMed) was limited to studies on the paediatric population and in English language between 2011 and 2019. Twenty-three relevant articles were found. Most of the articles did not demonstrate a major impact of these modalities in the general paediatric population. However, they may be beneficial in children with difficult intravenous access. Appropriate simulator mannequins should be utilised to train healthcare providers in using these vein finder devices.

Keywords: infrared, vein visualisation device, intravenous access, children, cannulation.

Anaesthesiol Intensive Ther 2021; 53, 1: 69–78

Received: 19.08.2020, **accepted:** 28.12.2020

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Peripheral venous access (PVA) is the backbone of inpatient management in all age groups. This can occasionally be very challenging in paediatric patients because of tortuous veins, dense subcutaneous fat, and an angry, uncooperative child [1]. The average number of punctures needed to successfully insert peripheral venous catheters in children in one study was 2.35, with a range of up to 10.5 [2]. These repeated punctures add to the stress of the doctor, parent, and patient and may even lead to a delay in treatment. This problem is even more serious in obese subjects and patients who need frequent infusions. For patients with circulatory collapse, it may also be difficult to place the PVA. This increases the need for centrally placed lines exposing the children to invasive procedures and the risk of infection. Subsequently, many vein finder devices came onto the market to help identify and cannulate a suitable vein.

The less common uses of vein visualisation devices are delineation of cortical veins prior to dura opening [3], avoidance of accidental intravenous injections of dermal fillers [4], preoperative identification of a suitable vein for lymphatico-venous anastomosis for lymphoedema management [5], reduction of injury to saphenous structures caused by insertion of a screw during arthroscopic ankle arthrodesis [6], etc.

INFRARED VEIN VISUALISATION DEVICES – HISTORY AND MECHANISM OF ACTION

Herbert Zeman invented the first vein-finding device in 1995 to image subcutaneous veins [7]. Many of these devices utilise near-infrared light that is presented on the skin surface. This light is absorbed in the blood vessels by haemoglobin, while in the remaining tissues it is reflected. This system processes the returned images, adds colour, and displays the image in real time on the skin surface. It supports the visualisation of the veins and identifies bifurcations to enhance access to the vein without the need for several punctures [8]. It also allows visualisation and refilling of veins, and the possibility of extravasation is thus minimised. Vein finder devices may help to distinguish a healthy vein from a sclerotic vein.

The various models of vein-finder devices include portable handheld and hand-free devices that can be used at the bedside in the hospital, as well as new versions of these devices with improved maneuvering and configuration options.

SPECIFICATION OF VEIN FINDERS

An ideal vein viewer should be portable, handheld, and with weight not exceeding 500 g. It should emit infrared wavelengths of min 850 mm with vein size visibility ≥ 1 mm and accuracy 0.25 mm.

The image frame rate should reach more than 20 f/s, allowing the flow of blood and injecting liquid medicine to be inspected clearly, which is critical when determining the consistency of the veins, punctures and other medical procedures of patients in clinical application. It should be designed with technologies that can adjust the picture brightness for the healthcare context [9]. It must be adjusted to the different lighting conditions, to provide a better visual experience and protect health workers from visual exhaustion.

VARIOUS DEVICES

Although most of these devices render blood vessels visible with near-infrared light, every device has a special mechanism for displaying the image (Figure 1). The most commonly used devices are listed below:

1. VeinViewer (Christy Medical Corporation, Memphis, TN, USA): AVIN (Active Vascular Imaging Navigation) patented technology was first incorporated in the VeinViewer in 2006. It is reported to display veins up to 10 mm deep and blood flow up to 15 mm deep. The VeinViewer is a non-invasive tool that projects infrared light on the skin of a patient. This makes sub-surface vessels visible using the reflection of near-infrared light. The light reflected is captured by a digital video camera. A microprocessor is used to apply contrast to the image of the veins and it is forecasted onto the skin in real time. It also defines where valves and bifurcations are located, and avoids these troublesome structures [10]. The VeinViewer has so far been tested most extensively in randomised trials. The products of VeinViewer include VeinViewer Flex and VeinViewer Vision.
   A. VeinViewer Flex (Christie Medical Corporation, Memphis, TN, USA): It has a basic 'Universal' imaging mode, which is useful for all patients. Other modes are 'Fine Detail', perfect for identifying small veins in paediatric patients, and 'Inverse' mode, which is ideal for darker skin and the identification of vein edges [11].
   B. VeinViewer Vision (Christie Medical Holdings, Inc., Memphis, TN, USA): This provides additional configuration options, e.g. adjusting image colour, inverting or resising the image, enhancing the image in fine detail mode and increasing or decreasing image brightness, or capturing and storing an image PNG file [12].
2. AccuVein (AccuVein AV300/400/500; Avant Medical, Cold Spring Harbor, NY, USA): This is also based on near-infrared light technology. The image formed is projected on the site of the puncture. Through the use of optional wheeled or fixed stands, it can easily be modified into a hands-free device [13].
3. VascuLuminator (de Konigh Medical Systems, Arnhem, the Netherlands): This device works using near-infrared light technology. The image appears on a monitor above the point of piercing the vein [14].
4. Veinsite (VueTek Scientific, Gray, ME, USA): This also uses near-infrared light. It has an optional

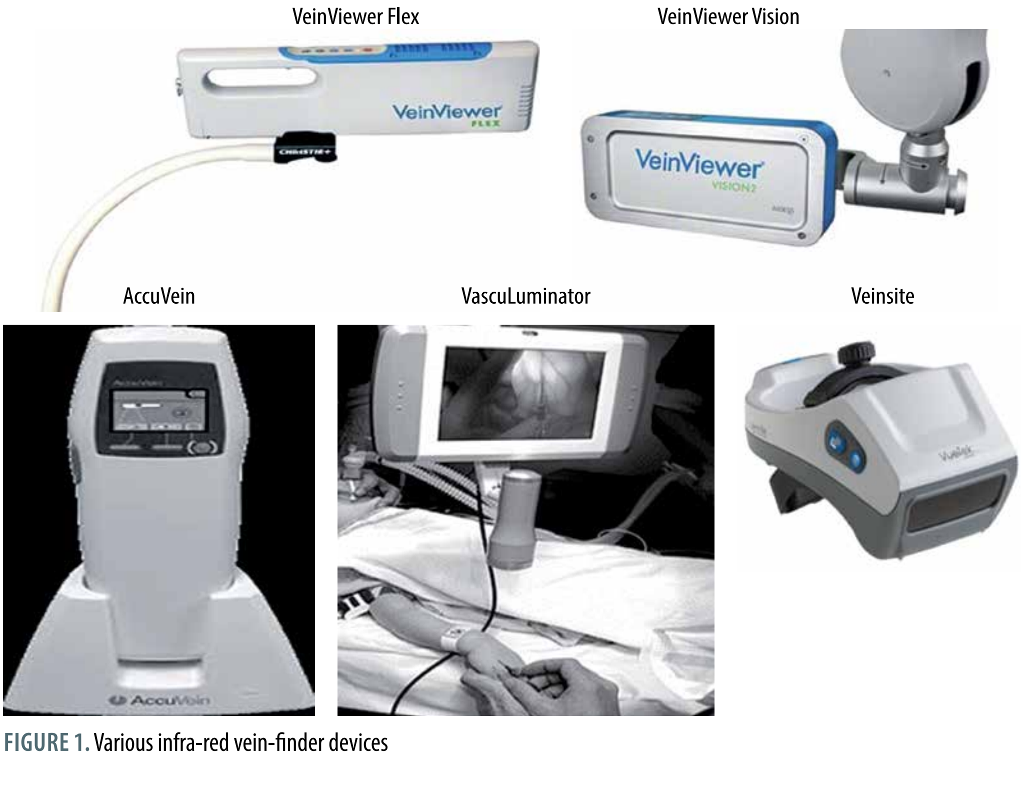

FIGURE 1. Various infra-red vein-finder devices

Video Graphics Array (VGA) cable of separate display on a monitor. It is worn on the head such that the whole anatomy of the patient's vein can be conveniently adjusted with a simple head movement during vein evaluation. The biggest advantage of this is that both of the clinician's hands are still available for the entire venous examination and venipuncture process [15].

GROUND REALITY – CLINICAL TRIALS

Search methodology

The databases Cochrane Library, Google Scholar and PubMed were searched between 2011 to 2019 using the subject keywords "intravenous", "near-infrared devices", "peripheral intravenous access", and others (Appendix 1). The search was restricted to studies involving children and written in English language. A total of 23 relevant articles (Figure 2) we found regarding use of an infrared vein visualisation device in the paediatric population [2, 16–37]. They include 3 meta-analyses: the latest from 2017 in Chinese language (abstract available in English) by Kuo *et al*. (including 12 articles), another one by Park *et al*. from 2016 (including 11 studies), and Heinrichs *et al*. from 2013 (including 3 studies), 18 randomised control trials (RCTs), 1 cohort, and 1 retrospective study (Table 1). Each publication was reviewed independently by 2 authors (VV and AS) to identify the author, country, publication year, infrared device used, age of patients, clinical setting, type of study, age group, outcomes (i.e. time for cannulation, first attempt success rate), results, and conclusions.

The most recent meta-analysis by Kuo *et al*. from 2017, which included 12 studies, established that vein-finder devices were unable to dramatically change the number of attempts required or the success rate of the first attempt, or the processing duration of PVA in children [19]. However, subgroup analysis showed that children who had difficulty with intravenous access had a considerably enhanced success rate of the first attempt with the help of a vein-finder device (OR = 1.83, $P = 0.03$). It has been proposed that the difficult intravenous access score could be a screening tool for paediatric patients with challenging peripheral intravenous access to use near-infrared devices to optimise intervention effectiveness. Another meta-analysis by Park *et al*. from the year 2016, which included 11 studies, showed a similar result, revealing that there is no real advantage of utilising near-infrared devices for intravenous cannulation in the paediatric population [21]. But for patients with difficult cannulation scenarios, this tool may be helpful. Heinrichs *et al*. in 2013 published a meta-analysis including 3 RCTs of vein-viewer devices, showing

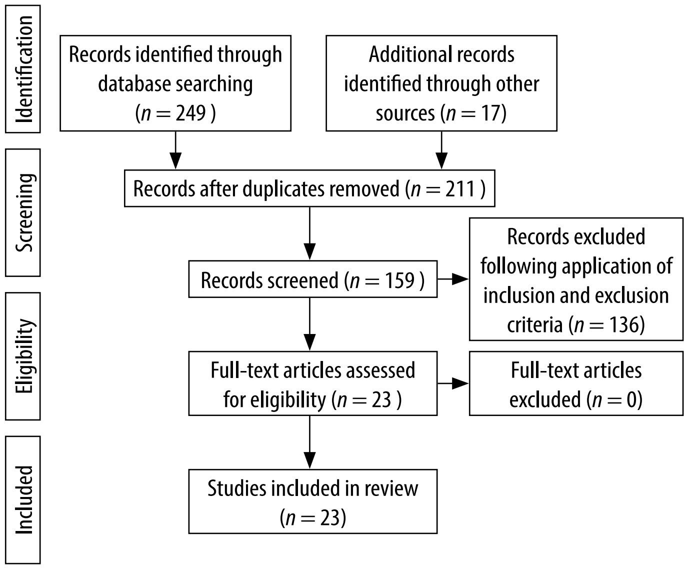

FIGURE 2. Flow diagram

no difference in first attempt performance in access of a PVA (RR = 0.99; CI: 0.74–1.33) [28]. They further mentioned that in selected subpopulations, such tools might be beneficial, but the evidence currently available does not support an advantage in the paediatric population.

Out of 18 RCTs, 2 included (Caglar *et al*. [16] and Phipps *et al*. [35]) preterm and term neonates. Caglar *et al*. used an AccuVein device in 30 patients in a NICU (neonatal intensive care unit) and observed that it needed less time for successful cannulation and yielded higher success of the initial attempt with a low Neonatal Infant Pain Scale score [16]. Similarly, Phipps *et al*. noted the successful placement of PVA in 86% in the VeinViewer group versus 75% in the control group ($P = 0.08$) [35]. They inferred that the VeinViewer increased PVA performance with the geatest benefit among infants of higher gestational age.

Only 3 RCTs with vein-finder devices were found in infants and young children [17, 29, 37]. Inal *et al*. [29] investigated the AccuVein device in 27 children aged 0–3 years and found that PVA was accessed with fewer attempts and with a shorter duration in the study group. The success rate at first attempt in the research group was 74.1%, while in the control group it was 40.7% ($P = 0.028$). Also, the pain intensity as evaluated by the FLACC (Face, Legs, Activity, Cry, Consolability) scale was substantially lower in the research group in comparison to the control group ($P < 0.05$). Comparably, Chapman *et al*. [37] in their study on 107 children aged 0 to 2 years found a notable reduction in the time to place the peripheral intravenous line, from 167 seconds in the control group to 121 seconds in the VeinViewer group ($P = 0.047$). The nurses' perception of pain was also lower (median VAS 34 in the study group vs. 46 in the standard group, $P = 0.01$). Contrary to this, Con-

TABLE 1. Details of various articles of infra-red vein-finder devices in chronological order

Author, year, country	Device name	Setup	Study design	Age group	Number of patients/ participants	Outcomes	Results	Conclusion
Caglar [16], 2019, Turkey	AccuVein AV400	NICU	RCT	32 to 37 gestational weeks	90	Primary – time to successful cannulation and success of the first attempt Secondary – dwell time and technique-related pain scores.	Less time to successful cannulation, higher success of the first attempt, lower Neonatal Infant Pain Scale scores, but longer dwell time of the PIVC placement	Infrared device provides efficacy in time to successful cannulation, success of the first attempt, length of the time the catheter is in place, and technique-related pain
Conversano [17], 2018, Itlay	VeinViewer Flex	Blood drawing center	Open, pseudo-RCT with 2 parallel arms	0–18 years 3 subgroups (< 5 years, 6–10 years, > 10 years)	115	Primary – time to perform blood sampling Secondary – first attempt success rate in blood sampling	No difference was found in duration of blood sampling and success at the first attempt in all the 3 age subgroups	Routine use of VeinViewer is not useful to reduce the time of the procedure during venipuncture
McNeely [18], 2018, USA	VeinViewer	Inpatient medical unit	Longitudinal experimental design with randomisation of non-blinded subjects	Standard practice group mean 8.87 years (SD = 6.79) and VeinViewer group mean 9.19 years (SD = 6.41)	40 nurses	Success of placement, number of attempts, and overall cost	No significant differences between VeinViewer use and standard practice	No difference was noted in perceived skills or confidence with insertion of PIVs
Kuo [19], 2017, China	Near-infrared devices	Paediatric clinical settings	Meta-analysis	Children	12 articles	First-attempt success rate, number of attempts, or the procedural time	It did not significantly improve the first-attempt success rate, number of attempts, or the procedural time of peripheral intravenous access in children	Near-infrared devices may improve the first-attempt success rate in children with difficult intravenous access
Demir [20], 2017, Turkey	AccuVein AV400	Paediatric inpatient	RCT	3 to 18 years	129	Number of attempts per patient, the duration of the procedure, and the first-attempt success rate	Reduced the number of attempts per patient and the operation duration but increased the rate of first-attempt success	Vein visualisation device support improves the success of peripheral intravenous catheterisation
Park [21] 2016, Korea	Near-infrared devices	Paediatric clinical settings	Meta-analysis	Children	11 studies	Failure rate at the first attempt, and the effect size was measured by the risk ratio for failure	No overall benefit of using near-infrared light devices for paediatric peripheral intravenous cannulation	But, this device might be useful for the patients in conditions difficult for successful cannulation
Ramer [22] 2015, USA	VeinViewer	Paediatric haematology-oncology clinic	Prospective, randomised cohort study	1–21 years	53 patients	Number of attempts, procedural time, access complications, and patient and nurse satisfaction	VeinViewer group required significantly less time to access a vein as compared with the standard – methods group	These patients rated nurses as having significantly more skill than nurses who did not use the VeinViewer

TABLE 1. Cont.

Author, year, country	Device name	Setup	Study design	Age group	Number of patients/ participants	Outcomes	Results	Conclusion
Curtis [23] 2015, Canada	VeinViewer	Paediatric emergency department	RCT	Children aged 16 or younger	418	Primary – successful intravenous catheterisation on the first attempt Secondary – number of attempts and time to successful placement	No significant difference in successful intravenous catheterisation on the first attempt, number of attempts, and time to successful placement	It does not support investment in this technology for routine peripheral intravenous catheterisation in children
Rothbart [24] 2015, Germany	AccuVein AV300	Preceding surgical interventions	Retrospective	0–17 years	238	Time and number of attempts until successful venous cannulation were defined as primary end points	Longer median time until successful cannulation, higher number of attempts, and lower rate of cannulations successful at first attempt in AccuVein group	It cannot be recommended for standard procedures
de Graaff [25] 2014, Netherlands	Vascu-Luminator	Outpatient clinic	Cluster randomized clinical trial	Younger than 18 years	226	Success at first attempt and time to successful cannulation	Success at first attempt in the group with the VascuLuminator and time to successful cannulation not significantly different from the control	It did not improve success of PIVC in paediatric patients who are known to be difficult to cannulate
Curtis [26] 2014, Canada	VeinViewer	Paediatric emergency department	Prospective RCT	0–16 years	400	Primary – rate of success of the initial attempt at PIV Secondary – number of IV punctures required to achieve successful PIVC placement, time taken to achieve successful PIVC placement and improved nursing satisfaction	Overall success of IV placement on first attempt was similar across study	VeinViewer did not improve first-attempt success rate, number of cannulation attempts, or speed of cannulation
Szmuk [27] 2013, USA	VeinViewer	Nonemergent peripheral IV access requirement	RCT	0–18 years	600	Primary – first-attempt insertion success Secondary – relationship between obesity and cannulation success	First-attempt cannulation success was 47% in patients assigned to VeinViewer vs. 62% in patients assigned to routine cannulation	VeinViewer worsened first-attempt IV insertion success by skilled nurses Surprisingly, first-attempt success for IV cannulation was not worsened by obesity

TABLE 1. Cont.

Author, year, country	Device name	Setup	Study design	Age group	Number of patients/ participants	Outcomes	Results	Conclusion
de Graaff [2] 2013, Netherlands	3 devices comparison 1. VeinViewer, 2. AccuVein AV300, 3. VascuLuminator Vision	OR	Cluster RCT	0–18 years	1913	Success at the first attempt	Suitable veins for cannulation were more easily visible with the VeinViewer (95.3%) and AccuVein (94.1%) devices than with the VascuLuminator (89.1%) ($P = 0.03$) However, success at the first attempt was not significantly different among groups, ranging from 73.1% to 75.3% ($P = 0.93$)	Vein visibility is enhanced, but these devices do not improve cannulation
Heinrichs [28] 2013, Canada	VeinViewer	Clinical settings	Meta-analysis	Children	3 RCTS	Number of attempts to successful PIVC and time to successful placement of IV line	Near-infrared light devices do not impact the risk of first-attempt PIVC failure	Near-infrared light devices might be efficacious in selected subpopulations, but the available evidence does not support an overall benefit in the paediatric population
Inal [29] 2013, Turkey	AccuVein AV400	Paediatric clinics	RCT	0–3 years	54	Primary – success rate and pain levels in paediatric patients during PIVC procedures Secondary – difficulty degree of the vein affected the success rate in visualisation-supported PIVC placement	Reduces the number of attempts per patient, reduces the duration of the procedure, and increases the success rate of first attempts, and there is procedural pain	Vein visualisation device improves the success of PIVC
van der Woude [30], 2013, Netherlands	VascuLuminator	OR	Pragmatic cluster RCT	0–15 years	111	Primary – success at first attempt Secondary – time to successful cannulation, whether the procedure succeeded, and helpfulness of the VascuLuminator	Success at first attempt was 63% in the VascuLuminator group vs. 51% in the control group ($P = 0.27$) No significant difference in time to successful cannulation in both groups	It has limited value in improving success at first attempt of facilitating IV cannulation in children with dark skin colour
Sun [31] 2013, Taiwan	VeinViewer	PICU	Randomised prospective observation trial	3 months to 17 years	60	Time taken to find the first available vessel and number of attempts	Less time required to find the first available vessel, fewer attempts, and shorter total time of attempts per patient in the near-infrared light device group	It can decrease the total medical time and cost in critical care

TABLE 1. Cont.

Author, year, country	Device name	Setup	Study design	Age group	Number of patients/ participants	Outcomes	Results	Conclusion
Kim [32] 2012, Korea	VeinViewer	Paediatric ward	RCT	1 month to 16 years	111	First-attempt success rate	The overall first-attempt success rate was 69.4%, i.e. 77/111 in the VeinViewer group and 38/57 in the control group, a difference that was not statistically significant However, the first-attempt success rate increased from 5/20 in the control group to 14/24 in the VeinViewer group for difficult veins with a DIVA score greater than 4 ($P = 0.026$) No differences in procedural time between 2 groups	The VeinViewer facilitated peripheral venous access for paediatric patients with difficult veins, which enhanced first-attempt success rates
Kaddoum [33] 2012, USA	AccuVein AV300	Patients under anaesthesia	RCT	0–18 years	146	Primary – success of the first attempt at cannulation Secondary – number of skin punctures and time to successful IV cannulation	The difference between the 2 treatment groups in number of skin punctures and the time to insertion was not significant	Although the AV300 was easy to use and improved visualisation of the veins, we found no evidence that it was superior to the standard method of intravenous cannulation in unselected paediatric patients under anaesthesia
Cuper [34] 2012, Netherlands	VascuLuminator	OR	Cluster RCT	0–18 years	770	Primary – success at first attempt Secondary – time to successful cannulation	No significant difference in success at first attempt with (70%) and without (71%) the use of the VascuLuminator ($P = 0.69$) No significant difference in time to successful cannulation in both groups	Although it was possible to visualise veins with NIR in most patients, the VascuLuminator did not improve success rate or time to obtain intravenous cannulation
Phipps [35] 2012, USA	VeinViewer	Level 3 NICU	RCT	Preterm and term neonates	115	To determine if VeinViewer use would increase successful line placement, with standard technique	Successful placement 86% in VeinViewer vs. 75% in control group; $P = 0.08$	Improved successful placement, with the most benefit seen in infants with greater GA

TABLE 1. Cont.

Author, year, country	Device name	Setup	Study design	Age group	Number of patients/ participants	Outcomes	Results	Conclusion
Perry [36] 2011, Hawaii	VeinViewer	Day Care	RCT	Younger than 20 years	123	First-attempt success rate for IV catheter placement	No significant difference in first-attempt success rate between the standard (79.0%) and device (72.1%)	Nurses placing PIVC reported several benefits in using of the device
Chapman [37] 2011, USA	VeinViewer	Paediatric Emergency Department	RCT	0–17 years	323	Primary – time to peripheral intravenous catheter (PIV) placement Secondary – number of PIV attempts, pain scores	Overall study group – no differences in time to PIV placement, number of PIV attempts, or pain scores subgroup analysis – age 0 to 2 years ($n = 107$) – significant results for mean time to place the PIV (121 seconds [VeinViewer group] vs. 167 seconds [standard group], $P = 0.047$) and for nurses' perception of pain (median VAS 34 [VeinViewer group] vs. 46 [standard group], $P = 0.01$)	VeinViewer may decrease time to IV catheter placement in young children and infants However, it did not demonstrate significant benefits in older children

PIVC – peripheral intravenous cannulation, RCT – randomised control trial, OR – operation room, NICU – neonatal intensive care unit

versano *et al*. [17] in 2018 in their sub-group analysis on children less than 5 years old noted that routine use of the VeinViewer was not beneficial for reducing procedure time and enhancing the performance of a cannulation attempt.

Other RCTs included a wider age range of children, up to 18 years of age. Most of these RCTs (Conversano *et al*. [17], McNeely *et al*. [18], Curtis *et al*. [23], de Graaff *et al*. [25], Szmuk *et al*. [27], Woude *et al*. [30], Kaddoum *et al*. [33], Cuper *et al*. [34], and Perry *et al*. [36]) did not find a vein-finder device worthwhile for paediatric peripheral intravenous cannulation. However, 4 RCTs (Demir *et al*. [20], Inal *et al*. [29], Sun *et al*. [31], and Kim *et al.* [32]) led to the conclusion that these tools increase the success of intravenous cannulation in paediatric patients. Ramer *et al.* [22], in their cohort study on 53 patients in a paediatric haemato-oncology clinic, noted that in the VeinViewer group it took less time to get into a vein than when using the standard method. In contrast, the only retrospective study, by Rothbart *et al*. [24] on 238 paediatric patients posted for various surgical interventions, showed that there was more time and an increased number of attempts needed for the AccuVein device. They further stated that it could not be advocated for regular peripheral intravenous cannulation in the paediatric population.

The reason why the performance rate is not improved with the vein-finder device is that it shows the particular vessel in 2 dimensions, which prevents the estimation of the vessel's exact depth. In addition, images of the vessel may become blurred while the catheter is positioned through the skin, and there may be a lack of hand-eye coordination. Anxiety and uncooperative paediatric patients can also affect cannulation [21]. Excessive anxiety of the operator and patient discomfort make it difficult to succeed in further attempts if the first attempt fails. The clinician's experience in cannulation and their familiarity with these devices can also influence their performance [28].

CONCLUSIONS

In summary, establishing peripheral venous access in a child may occasionally be very difficult, and a device that provides assistance would be welcome in all paediatric acute care, intensive care, and operating room settings. Most of the trials we reviewed did not demonstrate a major impact of these modalities. However, we must keep in mind the many cofounding factors such as the ethnicity and hence the complexion of the child, the amount of subcutaneous fat, and whether the child is coming to the hospital for the first time or has received multiple prolonged infusions that sclerose and damage the veins. Also, the expertise of the person attempting to insert the intravenous line with and without the vein finding device is equally important. Furthermore, vein-finding devices are relatively costly and may not be readily available in smaller hospitals and clinics. In clinical settings, we strongly suggest that vein-finder devices should be taken into consideration if PIVC (peripheral intravenous cannulation) is anticipated to be difficult. Appropriate simulator mannequins should be utilised to train healthcare providers in using these vein finder devices. The utility of vein finder devices should be further established in different scenarios (e.g. emergency vs. elective), and by identifying appropriate patient subgroups.

ACKNOWLEDGEMENTS

1. Financial support and sponsorship: none.
2. Conflicts of interest: none.

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APPENDIX 1

SEARCH

The aforementioned search terms were used to search PubMed and were adjusted for the other databases:

1. (Near infrared light) OR (Vein Visualization Devices)) OR (near infrared light)) OR (VeinViewer)) OR (Near-Infrared)) OR (Vein Visualization Device)) OR (near-infrared)) OR (NIR)) OR (veinviewer)) OR (peripheral intravenous cannulation)) OR (Near-infrared light)) OR (AccuVein)) OR (Near-infrared)) OR (VeinViewer)) OR (VeinViewer-assisted)
2. (children) OR (Infants)) OR (pediatric)) OR (Children)) OR (Pediatric)) OR (Pediatr)) OR (infants and children)) OR (Pediatric)) OR (neonates)
3. #1 AND #2
4. (intravenous) OR (venous)) OR (Intravenous)) OR (blood drawing)) OR (Peripheral Venous)) OR (IV)) OR (Peripheral Venous)) OR (peripherally)
5. #3 AND #4
6. (cannulation) OR (Catheter)) OR (success)) OR (catheter)) OR (Access)) OR (catheterization)) OR (access)) OR (catheters)
7. #5 AND # 6