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CLINICAL PRACTICE

# Vein visualization: patient characteristic factors and efficacy of a new infrared vein finder technology†

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## Editor's key points

- Factors contributing to difficult venous cannulation and the impact of new vein imaging technologies are important to safe and effective medical therapy.
- The numbers of potential i.v. cannulation sites were compared using the conventional visual method and a new infrared vein finding technology.
- Infrared vein visualization increased the number of potential cannulation sites in all subgroups.

**Background.** We investigated the patient characteristic factors that correlate with identification of i.v. cannulation sites with normal eyesight. We evaluated a new infrared vein finding (VF) technology device in identifying i.v. cannulation sites.

**Methods.** Each subject underwent two observations: one using the conventional method (CM) of normal, unassisted eyesight and the other with the infrared VF device, VueTek's Veinsite™ (VF). A power analysis for moderate effect size ($\beta$=0.95) required 54 samples for within-subject differences.

**Results.** Patient characteristic profiles were obtained from 384 subjects (768 observations). Our sample population exhibited an overall average of 5.8 [95% confidence interval (CI) 5.4–6.2] veins using CM. As a whole, CM vein visualization were less effective among obese [4.5 (95% CI 3.8–5.3)], African-American [4.6 (95% CI 3.6–5.5 veins)], and Asian [5.1 (95% CI 4.1–6.0)] subjects. Next, the VF technology identified an average of 9.1 (95% CI 8.6–9.5) possible cannulation sites compared with CM [average of 5.8 (95% CI 5.4–6.2)]. Seventy-six obese subjects had an average of 4.5 (95% CI 3.8–5.3) and 8.2 (95% CI 7.4–9.1) veins viewable by CM and VF, respectively. In dark skin subjects, 9.1 (95% CI 8.3–9.9) veins were visible by VF compared with 5.4 (95% CI 4.8–6.0) with CM.

**Conclusions.** African-American or Asian ethnicity, and obesity were associated with decreased vein visibility. The visibility of veins eligible for cannulation increased for all subgroups using a new infrared device.

**Keywords:** catheterization; veins

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Establishing peripheral i.v. access is an invasive procedure critical to medical care. Despite this, clinicians and researchers know little about the characteristics of having many or few veins aside from anecdotal reports and experiences. Surprisingly, there is currently no literature about the number of veins visible in patients or the patient characteristics associated with difficult i.v. access. Previous studies reported various factors that affect vein visibility required for vein cannulation, but none has investigated patient characteristics and skin colour specifically.[1–7] Our study investigated patient characteristics associated with finding veins eligible for cannulation.

As life expectancy increases and patients have more procedures throughout their lifetime, vein preservation is seen as a vital long-term task. A device or technique that helps reduce cannulation attempts would be one step towards vein preservation. Technical advances and substantial research have allowed healthcare providers to improve the ease and speed of placing i.v. catheters.[4 7–9] Some studies have focused on techniques and devices to improve vein visibility. Our study examined visualization of superficial veins with a new infrared technology. There are several devices using this technology including the AccuVein® and VeinViewer®. We chose to study the VueTek Scientific Veinsite that was designed to improve the visualization of superficial veins. This is the first study for this particular device.

There were two objectives of this study. First, we investigated the patient characteristic factors that correlate with identification of vein cannulation sites with the conventional method (CM) or first accurate visual check. Secondly, we sought to evaluate the new infrared vein finding (VF) technology device in identifying i.v. cannulation sites on the upper extremity. We hypothesized that obesity, dark skin colour, and younger age would be associated with finding fewer veins. We also proposed that the infrared technology would allow finding of more potential cannulation sites.

† This article is accompanied by Editorial II.

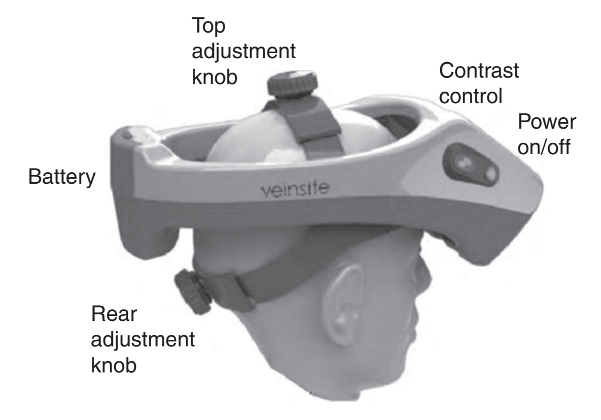


**Fig 1** Veinsite™ headset diagram.[12]

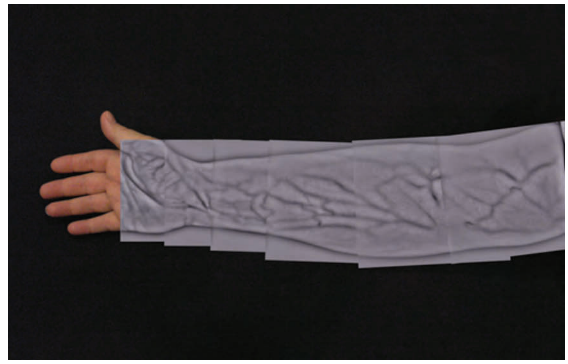

**Fig 2** View of upper extremity veins seen with the VueTek Veinsite™.

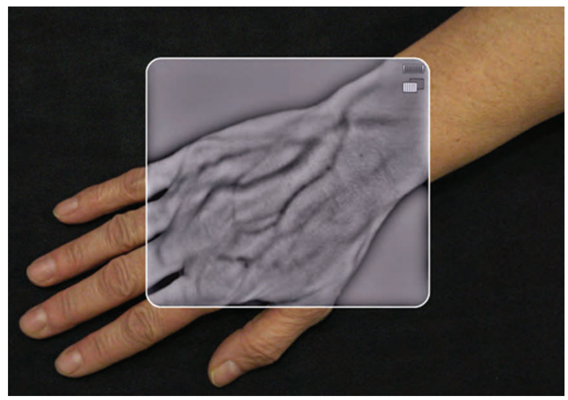

**Fig 3** View of veins seen with the VueTek Veinsite™.

## Methods

After receiving Institutional Review Board approval, a randomized prospective study was conducted on volunteer subjects at a large urban medical centre, St Luke's-Roosevelt Hospital Center. Study participants included males and females of all ages, irrespective of race or ethnicity. Excluded conditions were emergency surgeries or pregnancy. Before involvement in the study, written informed consent was obtained from all subjects or their parents if subjects were under the age of 18 or unemancipated minors. Patient characteristic information including age, gender, height (inches), weight (pounds), ethnicity, and skin colour (Von Luschan's chromatic scale)[10] was collected from each study participant. Observers, including phlebotomists, physicians, and nurses skilled in venipuncture, examined a minimum of 10 independent subjects each. Difficult cases were defined as zero or one vein visible by the CM.

We inspected the upper extremities, defined as the forearm and hand distal to the elbow crease, of all subjects for possible venipuncture sites. Each subject underwent two observations: one using the CM and the other with the VF device. When the order called for CM, we used normal, unassisted eyesight. With the VF condition, we used the head-mounted VueTek Veinsite™ system (Grey, ME, USA), which included a portable near-infrared (NIR) emitter, video acquisition, and display device (Fig. 1). The company did not participate in the formation, design, implementation, or reporting of the study. The VF uses a rechargeable battery, and also has an optional VGA cable for separate monitor display. The device allows for concurrent vein inspection with normal eyesight and operates independently of ambient light conditions. When powered on, it emits NIR radiation (range, 700–900 nm), penetrating human anatomy deeper than visible light (<700 nm). Upon contact with tissue, NIR light (tissue absorption coefficient between 0.02 and 0.3 $cm^{-1}$) scatters, travelling a depth of <5 mm before deviating from its initial direction.[11] Conversely, haemoglobin and other vascular fluids are highly absorptive. The Veinsite's electro-optical technology detects the absorption difference between vascular structures and surrounding tissue. After converting the raw image to greyscale, it then displays it on the headset's LCD screen (Figs 2 and 3). Consequently, the user experiences a near real time, enhanced video of the vascular system.[12]

The CM and VF sequence was pre-determined by a computerized random number generator and not revealed to the subject or operator until the actual observation. Upon request, the subject exposed a single upper extremity. The observer then rotated the upper extremity and hand while counting the number of visible veins eligible for cannulation. Each continuous vein was counted as one cannulation site. Each operator counted out loud the number of veins seen, and a research assistant then recorded this number. Using the same arm, the next method in the sequence was implemented. Both CM and VF methods required an unobstructed view of the subject's arm under standard hospital lighting conditions. Direct skin contact and the use of tourniquets were strictly avoided. There was no vein diameter, length, or joint criteria. It was an experienced operator counting the sites they felt would be suitable for cannulation.

For the VF method, each observer was trained in the proper use of the device at a training session before examining their first subject. Before examining any subjects, operators were shown the device. The power button, viewing lens, and head strap adjustment knobs were identified. The operator was then allowed to look at the device and place it on the head. After adjusting the head strap, they then were able to examine two volunteers' arms to become familiar with device use. Comfort and ergonomic ratings were recorded, and feedback on the device was solicited. Research assistants recorded the time from the mounting of VF device to its operation for each study subject.

### Statistical analysis

The Analyze-it add-in for Microsoft Excel (Redmond, WA, USA) provided the analysis used for the study. BMI was defined as weight (lb) multiplied by 703 and divided by height$^2$ (in$^2$). The proportional significance across patient characteristic groups (age, gender, ethnicity, and BMI) was determined by the Pearson $\chi^2$ test. One-way analysis of variance (ANOVA) provided comparisons of CM and VF visible vein averages. The original power analysis for moderate effect size and $\beta$=0.90 for within-subject differences (VF *vs* CM) required 54 subjects. However, we were interested in patient characteristic differences as well (secondary analyses) such as age, gender, ethnicity, and BMI. We extended the study to 384 subjects to accommodate subgroup analyses recognizing that some subgroups could be underrepresented. For example, neonates ($n$=13) or morbidly obese ($n$=11) subjects have inadequate power. When combined with 'obese' ($n$=65), there is adequate power, for example, 'obese plus morbidly obese' equals 76 subjects. However, we did not power the study for these particular subgroups. Categorical and continuous data are presented as percentages and mean [95% confidence interval (CI)], respectively. $P$-values of <0.05 were considered significant.

**Table 1** Patient characteristic profiles. *Age groups are defined by ≤2 yr=(infant), >2 and ≤7 yr=(child), >7 and ≤18 yr=(adolescent), >18 and ≤40 yr=(young adult), >40 and ≤65 yr=(middle-aged), and >65=(elderly). †Skin colour measured using von Luschan scale: <26 (lighter); ≥26 (darker). ‡Weight defined using BMI:<18.5 (underweight); ≥18.5 (normal); ≥25 (overweight); ≥30 [obese including morbidly obese (BMI≥40)]. ¶Lower BMI sample size due to missing data

| Categories | No. (%) ($n$=384) |
|---|---|
| Gender | |
| Male | 152 (39.6) |
| Female | 232 (60.4) |
| Age* | |
| Infants (≤6 months) | 13 (3.4) |
| Infants (>6 months) | 15 (3.9) |
| Child/adolescent | 21 (5.5) |
| Young adult | 115 (29.9) |
| Middle-aged | 178 (46.4) |
| Elderly | 42 (10.9) |
| Ethnicity | |
| Caucasian | 182 (47.4) |
| African-American | 60 (15.6) |
| Asian | 44 (11.5) |
| Hispanic | 88 (22.9) |
| Multiracial | 10 (2.6) |
| Skin colour† | |
| Lighter | 244 (63.5) |
| Darker | 140 (36.5) |
| BMI‡ ($n$=381¶) | |
| Obese (BMI≥40) | 11 (2.9) |
| Obese (BMI<40) | 65 (16.9) |
| Overweight | 118 (31.0) |
| Normal | 153 (40.2) |
| Underweight | 34 (8.9) |

## Results

Patient characteristic profiles were obtained from 384 subjects (768 observations). Our population had an average age of 42.4 (95% CI 40.3–44.5 yr) ranging from <6 months old (3%) to beyond 65 yr of age (10.9%). It also included 232 females (60.4%) and 244 (63.5%) lighter-skinned subjects. Our sample had a representative distribution of ethnic groups, including 60 (15.6%) African-Americans and 44 (11.5%) Asians. A wide range of BMI [25.6 (95% CI 25.0–26.3)] was also included, with 76 (19.8%) subjects considered obese including 11(2.9%) morbidly obese (BMI≥40). One hundred and fifty-one (39.3%) had normal BMI (Table 1).

Our sample population exhibited an overall average of 5.8 (95% CI 5.4–6.2) veins using CM. ANOVA population comparisons suggested significant differences between age ($P$<0.0001), BMI ($P$<0.0001), and ethnicity ($P$<0.008) subgroups. Across all patient characteristic groups, vein detection was the lowest among infants <6 months [0.9 (95% CI 0.7–1.1) veins] and infants >6 months [2.3 (95% CI 2.0–2.6) veins]. They averaged 4.9 and 3.5, respectively, fewer veins than the population average of 5.8 (95% CI 5.4–6.2). Regression modelling suggested a positive correlation between overall age and visible vein count (Fig. 4; $r$=0.27, $P$<0.0001). As a whole, CM vein visualization showed a substantial decline among obese [4.5 (95% CI 3.8–5.3) veins], African-American [4.6 (95% CI 3.6–5.5) veins], and Asian [5.1 (95% CI 4.1–6.0) veins] subjects (Table 2). In particular, the morbidly obese exhibited only 3.6 (95% CI 1.5–5.8) veins.

Of the 384 subjects observed, 32 (8.3%) were considered difficult cases: nine subjects with no visible vascular structures and 23 with only one (Table 3). Age ($P$<0.0001), BMI ($P$=0.034), skin colour ($P$=0.0014), and ethnicity ($P$=0.0146) subgroups all showed a significant difference from their expected Pearson $\chi^2$ percentage values. Infant (50%), African-American (18.3%), Asian (9.1%), multiracial (20%), obese (10.5%), underweight (20.6%), and dark skinned subgroups (14.3%) exhibited a proportionally higher than expected number of difficult cases within their respective patient characteristics (Fig. 5).

The VF technology identified an average of 9.1 (95% CI 8.6–9.5) possible cannulation sites. Compared with CM, the overall

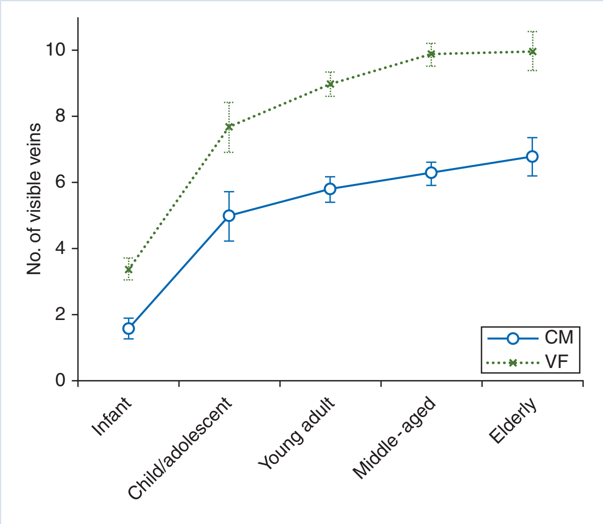


**Fig 4** Comparison of VF and CM visible sites [mean (SE)] across age groups.

**Table 2** Number of hand and forearm veins identified for attempted cannulation by CM. CI, confidence interval. **P*-values of <0.05 for categories with significant CM average differences across all groups. †See Table 1 for category definitions

| Categories† | Mean (95% CI) | *P*-value* |
|---|---|---|
| Gender | | |
| Male | 6.1 (5.5–6.7) | 0.1612 |
| Female | 5.6 (5.1–6.1) | |
| Age | | |
| Infant | 1.6 (1.1–2.1) | <0.0001 |
| Child/adolescent | 5.0 (3.8–6.2) | |
| Young adult | 5.8 (5.2–6.4) | |
| Middle-aged adults | 6.3 (5.8–6.9) | |
| Elderly | 6.8 (5.8–7.9) | |
| BMI | | |
| Obese | 4.5 (3.8–5.3) | <0.0001 |
| Overweight | 6.4 (5.7–7.0) | |
| Normal | 6.5 (6.0–7.0) | |
| Skin colour | | |
| Lighter | 6.0 (5.6–6.5) | 0.0956 |
| Darker | 5.4 (4.8–6.0) | |
| Ethnicity | | |
| Caucasian | 6.2 (5.6–7.2) | 0.008 |
| African-American | 4.6 (3.6–5.5) | |
| Asian | 5.1 (4.1–6.0) | |
| Hispanic | 6.4 (5.6–7.2) | |
| Multiracial | 4.7 (2.4–7.0) | |

average of additional veins found with VF was 3.3 (95% CI 3.0–3.5) veins. In 353 of 384 (92%) observations, the VF technology located at least one additional vein. Seventy-six (19.8%) obese subjects had an average of 4.5 (95% CI 3.8–5.3) and 8.2 (95% CI 7.4–9.1) veins viewable by CM and VF, respectively. Also, the morbidly obese visible vein count improved to 6.6 (95% CI 5.9–7.3) veins with VF from 3.6 (95% CI 1.5–5.8) with CM. In other groups, the VF identified the following number of veins: males 9.7 (95% CI 8.9–10.4), females 8.7 (95% CI 8.1–9.2), infants 3.4 (95% CI 2.7–4.0), child/adolescent 7.7 (95% CI 6.1–9.3), young adult 9.0 (95% CI 8.3–9.8), middle-aged adults 9.9 (95% CI 9.2–10.6), elderly 10.0 (95% CI 8.8–11.2), lighter skin 9.0 (95% CI 8.5–9.6), darker skin 9.1 (95% CI 8.3–9.9), Caucasian 9.1 (95% CI 8.5–9.8), African-American 8.5 (95% CI 7.3–9.8), Asian 7.5 (95% CI 6.4–8.6), and Hispanic 10.1 (95% CI 9.1–11.0).

**Table 3** Comparison of difficult and normal cases using the CM. Cases grouped by number of visible veins: zero or one (difficult), more than one (normal). **P*-values of <0.05 are considered significant. †See Table 1 for category definitions. ‡Groups with disproportionately higher number of difficult cases ($P$<0.05)

| Categories | Difficult no. (%) ($n$=32) | Normal no. (%) ($n$=352) | *P*-value* |
|---|---|---|---|
| Total | 32 (8.3%) | | |
| Gender | | | |
| Male | 14 (9.2) | 138 (90.8) | 0.6147 |
| Female | 18 (7.8) | 214 (92.2) | |
| Age† | | | |
| Infants (≤6 months) | 10 (76.9)‡ | 3 (23.1) | <0.0001 |
| Infants (>6 months) | 4 (26.7)‡ | 11 (73.3) | |
| Child/adolescent | 1 (4.8) | 20 (95.2) | |
| Young adult | 9 (7.8) | 106 (92.2) | |
| Middle-aged adult | 7 (3.9) | 171 (96.1) | |
| Elderly | 1 (2.4) | 41 (97.6) | |
| BMI† | | | |
| Obese | 8 (10.5)‡ | 68 (89.5) | 0.034 |
| Overweight | 8 (6.8) | 110 (93.2) | |
| Normal | 9 (5.9) | 144 (94.1) | |
| Skin colour | | | |
| Lighter | 12 (4.9) | 232 (95.1) | 0.0014 |
| Darker | 20 (14.3) | 120 (85.7) | |
| Ethnicity† | | | |
| Caucasian | 10 (5.5) | 172 (94.5) | 0.0146 |
| African American | 11 (18.3)‡ | 49 (81.7) | |
| Asian | 4 (9.1)‡ | 40 (90.9) | |
| Hispanic | 5 (5.7) | 83 (94.3) | |

The VF device was worn for an average of 5 min before comfort and ergonomic ratings at their training session. The time required to secure the device onto the operator's head before conducting observations averaged 7.8 (95% CI 7.2–8.4) s. In the pre- and post-study assessments, 14 operators conducting the study expressed no concerns with the device. Each operator examined an average of 27 subjects. The number of veins viewed was not significantly different by viewer.

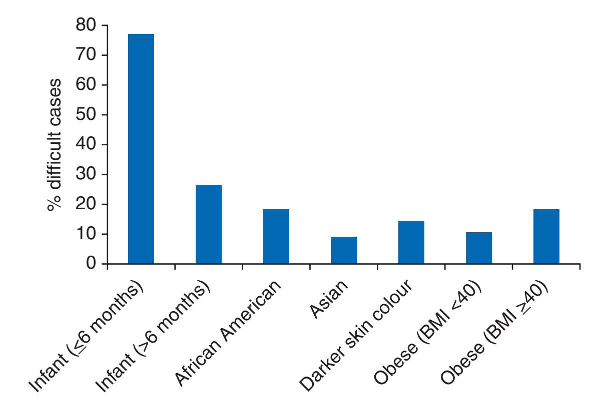


**Fig 5** Patient characteristic percentages of difficult cases within populations of interest. See Table 3 for difficult case definition.

# Discussion

## Patient characteristic factors

First, the study aimed to delineate how specific patient characteristics impact vein visibility. Anecdotally, physicians believe that extremes of age, obesity, dark skin colour, history of i.v. drug abuse, comorbid vascular conditions such as hypertension, and diabetes make i.v. access more difficult. Veins collapse or constrict with physiological changes such as intravascular volume depletion or increased sympathetic tone, respectively.[6] Visibility of superficial peripheral veins is also attributed to individual body habitus, deposition of adipose tissue, fluid status, blood velocity, and vein diameter.[5 8] For these reasons, the level of difficulty in i.v. access varies significantly based on patient characteristics.

Vein counts (range, 0–28 visible veins) showed a strong correlation with age (Fig. 5), appearing lowest in infants [1.6 (95% CI 1.1–2.1)] and highest among the elderly [6.8 (95% CI 5.8–7.9)]. We believe that this is due to the relocation of subcutaneous fat into visceral adipose tissue as age increases.[13 14] The regression model indicating infants' reduced number of visible veins should be tempered by the smaller sample size. Comparatively, obese subjects showed a moderately lower number of veins, possibly due to the additional subcutaneous fat reducing hypodermal transparency.[15] Among ethnic groups, the vein count of both African-Americans and Asians decreased farther below the population mean. We did not expect Asians to have fewer veins visible, but perhaps Asians have smaller vessel diameters contributing to reduced visibility.[16] All of our African-American subjects (100%) exhibited darker skin, a probable factor in difficult cases. However, due to our study's broader definition of darker skin with the Von Luschan's chromatic scale, all members of the darker skin colour group averaged 5.4 (95% CI 4.8–6.0), a less dramatic decrease from the population mean. Overall, our hypothesis held true for age and obesity, but ethnicity served as a better predictor of visibility than did skin colour.

We focused on the upper extremity for several reasons. This is a common site of venous cannulation. Although lower extremity veins can also be cannulated, it is usually not the first choice. It was also logistically easier to study forearms and hands as subjects have short sleeves or roll their sleeves up.

While emergency patients would be an interesting group to study, they are often not in the right state of mind to participate, and also likely have more variable acute medical issues that are not easily accounted for or measured in this initial study.

## Difficult cases

Whenever patients' veins are invisible to regular eyesight, complications can arise. During these difficult cases, blind cannulation and multiple attempts can be frustrating for medical professionals and painful for patients. Unsuccessful peripheral i.v. cannulation increases the chance of further complications such as bruising, bacterial infection, extravasation, phlebitis, thrombosis, embolism, or nerve damage.[17] It can also lead to even more invasive procedures resulting in higher rates of infection and requiring more operator skill (e.g. central line placement, peripherally inserted central catheters, intraosseous, and venous cut-downs are alternative, more complex techniques).[2 3]

In an effort to anticipate difficult i.v. access cases, practitioners habitually rely on patient characteristics (e.g. as extremes of age, obesity, and darker skin colour) as predictors.[7] Our study helped to provide patient characteristic data, defining difficult i.v. access as only occurring in subjects with less than two visible veins using CM ($n$=32). Overwhelmingly, infants ran the highest risk (50%) of such cases, although our results are tempered by a smaller sample size. African-Americans and morbidly obese subjects were also markedly high risk. In all, we believe that these characteristics serve as useful predictors for difficult i.v. cannulation cases.

## VF technology

To aid in difficult cannulation procedures, practitioners have enlisted the use of various technological devices (e.g. ultrasound).[1 4 7 8] While there are other vein viewing devices with infrared technology, for example, AccuVein®, VeinViewer®, we chose to study one such device. We do not know but have no reason to suspect that there would be major differences than those reported here. Our data analysis has demonstrated the significant enhancement of vein visualization through the use of a new VueTek's Veinsite™ NIR technology. With an overall increase of 3.3 (95% CI 3.0–3.5), VF consistently improved the average number of visible veins across all patient characteristic categories. In 92% of our cases, the infrared technology allowed the identification of at least one additional vein. There were 14 (3.6%) subjects with fewer veins seen by VF and, in 17 (4.4%) cases, there was no difference. The VF increased the detection of possible i.v. cannulation sites in most (97%) of the difficult cases ($n$=32) including 1.7 (95% CI 1.3–2.1) additional visible vein sites for the infant group and 3.7 (95% CI 3.1–4.2) for African-Americans. Obese subjects' vein visibility was also markedly improved by 4.0 (95% CI 3.2–4.8). Morbidly obese patients improved by 3.0 (95% CI 0.9–5.1). In summary, the results agree with our hypothesis, showing the efficacy and broad application of the infrared VF technology. We believe that the device will serve as a convenient, non-invasive tool for identifying potential cannulation sites, particularly for patients with zero or one vein visible as seen by normal eyesight.

When health professionals anticipate or encounter difficult i.v. access, they may consider this new VF technology a viable resource for vein detection. We feel that identifying more veins is one step towards cannulating more veins and that successful and timely i.v. cannulation leads to reduced tissue trauma, reduced economic costs, and higher patient satisfaction. Nonetheless, there is little research about success at cannulating veins that are identified with these new infrared technologies. The NIR technology is not three-dimensional, so this is a potential limitation related to the ability to cannulate the veins one sees.

### Limitations

Lack of comprehensive interviews with participants implies possible confounding factors. Conditions such as history of i.v. drug abuse, vascular disease, diabetes mellitus, and co-morbid hypertension affect visibility of superficial veins and should be included in the above analysis. This study did not use palpation or any supplemental method to increase venous prominence such as fist clenching, proximal venous tourniquet, application of heat, esmarch bandages, application of nitroglycerin ointment, or non-infrared devices such as ultrasound or transillumination.[1 3 6–8 18 19] Future research can investigate the above enumerated methods during actual i.v. cannulation trials.

## Conclusion

Our study investigated patient characteristics that influence the identification of veins available for i.v. access. Our findings contribute pertinent and new data on i.v. access. African-American or Asian ethnicity, and obese weight were all patient characteristic groups associated with decreased vein visibility. On average, our practitioners identified approximately six veins on each upper extremity using unassisted vision (CM). The visibility of superficial veins eligible for attempted i.v. cannulation consistently increased when using the new infrared VueTek Veinsite® device. These findings can serve as a basis for future studies. Early identification of patients with difficult i.v. access will lead to better clinical care, preventing complications and reducing delays in starting treatment.

## Declaration of interest

None declared.

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