An observational study comparing the prototype device with the existing device for the effective visualization of invisible veins in elderly patients in Japan

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Abstract

Objective: To compare the performance on the detection of the invisible veins between our modified prototype device and an existing device in elderly hospitalized patients.

Methods: A prospective, cross-sectional, and observational study was performed in the invisible veins in elderly patients. The major variables, skin color near the invisible veins, and diameter and depth of the invisible veins were measured. The vein visualization rate was calculated as the ratio of the visualized veins to the invisible veins by the visualization device.

Results: We analyzed 53 invisible veins in the cubital fossa and 56 invisible veins in the forearm in a total of 72 patients (median age, 73 years). The visualization rate for our prototype device was higher than that for an existing device in the cubital fossa and the forearm sites. The visualized veins of the prototype device had a higher intensity ratio than that of an existing device. No significant differences were observed in the body mass index, vein depth, and vein diameter of the visualized veins at the cubital fossa and forearm sites.

Conclusion: The prototype surpassed the existing device in visualizing the invisible veins. However, the prototype was unable to visualize all the invisible veins. We need to look for ways to reduce noise and to visualize the invisible veins, and the visualization rate of devices needs to be investigated in further association with the percentage of success with actual intravenous access and locating time to vein.

Keywords

Venipuncture, intravenous access, invisible vein, noninvasive visualization, image processing, near-infrared light

Introduction

To ensure the safety and certainty of peripheral intravenous (IV) access, attempting IV access on veins that are visible improves safety and the chance of success and has been recommended.[1,2] However, not all veins are visible, because they lack the characteristic color or venous distention of the skin surface even after the application of a tourniquet. Puncturing of the invisible peripheral veins reduces the chance of successful venipuncture[3,4] and may cause nerve damage.[5,6] Thus, healthcare providers require visual guidance when puncturing the invisible veins.

Several devices have been developed with near-infrared rays (NIR)-reflecting system for venous visualization. NIR can be transmitted through the subcutaneous tissue and is

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absorbed by hemoglobin in the blood.[7] Hence, we can easily acquire vascular images. However, the first-attempt success rates of these techniques are not significantly higher than those of conventional venipuncture.[8–10] One reason for no difference in successful venipuncture with or without visually guided device is a limit for penetration depth and quality of visualization possible using NIR. This led to some veins remaining invisible on using the marketed machine. Before performing venipuncture on patients, healthcare providers place more importance on the ability of vein visualization devices to visualize the invisible veins than on their ability to make the visible veins clearer. We modified our prototype using long wavelength light and adding image processing[11] to visualize deep and invisible peripheral veins.

Can we demonstrate that our modified prototype is superior to the existing devices? For a device to offer superior vein visualization, what variables of visualization must be superior? We conducted this study to answer these questions. In this study, we compared the performance on the detection of the invisible veins between our modified prototype device and an existing device (AccuVein® AV300; Avant Medical, Cold Spring Harbor, NY, USA) in elderly hospitalized patients.

Methods

Participants

The study protocol was approved by the Medical Ethics Committee of Kanazawa University. We conducted an observational, cross-sectional study with prospective data collection from December 2012 to March 2013 in two surgical wards and two internal medicine wards at a suburban hospital.

The inclusion criteria of patients were as follows: age >65 years, because there are many elderly persons in our country, and we expect more elderly patients in the future, occurrences of blood collection and catheter placement will increase; no IV access within the previous 2 days; no requirement for family intervention in obtaining consent; absence of skin lesions on the investigated site; and no veins visible at the investigated site. Patients were excluded if they were unstable or if emergency IV access was required. A clinical research associate contacted eligible patients and used an explanatory document to obtain informed consent for document review prior to enrollment. Clinical and demographic characteristics within 1 week of investigation were collected from medical records.

Measures

The research assistant measured the illumination intensity in each patient's bedroom using an illuminance meter (Digital Illuminance Meter Model 51001; Yokogawa Meters & Instruments Corporation, Tokyo, Japan). We proceeded with the investigation when the illumination intensity was ≥750 lx,

as recommended by the Japanese Industrial Standards Committee (Z-9110) for Clinical Examination and Injection.

We investigated the invisible veins at two sites on the nondominant upper extremity of each patient. The first investigational site was the cubital fossa site where longitudinal 4 cm area centered line connecting lateral epicondyle of humerus and medial epicondyle of humerus, which is used for blood collection; the second was the forearm site where longitudinal 5 cm area distal to cubital fossa site, which is used for peripheral venous catheter placement. The investigated vein was 1 cm long and invisible and comprised one of the cephalic, median antebrachial/median cubital or basilic veins. An invisible vein was defined as that lacking the characteristic color of a vein and venous distention on the skin surface following the application of 80 mmHg pressure to the upper extremity for 20 s.[12] The clinical research associate selected the investigated vein by palpation and rated it as an "invisible vein."

We determined the measurements for skin color, the diameter and the depth of the investigated vein, the subjective evaluation of the investigated vein using each device, and the intensity ratio of vein and subcutaneous tissue with the visualized veins.

Skin color was measured using a tristimulus colorimetric instrument (NF 333; Nippon Denshoku Industries Co., Ltd, Tokyo, Japan) and quantified according to the Commission International de l'Eclairage (CIE) $L^*a^*b^*$ values. Darkness of skin pigmentation affected vein visibility.[13] The CIE $L^*a^*b^*$ values may be the most commonly used quantification of skin color.[14] The L^* (luminance) value measures brightness ranging from total black (low values) to total white (high values). The a^* value expresses color from green (−) to red (+). The b^* values express color from blue (−) to yellow (+). The L^*, b^*, and melanin index values correlate almost linearly with the amount of epidermal melanin. The a^* values correlate almost linearly with the amount of hemoglobin being held constant.[15]

The depth and diameter of the investigated veins were measured using ultrasound with a 15-MHz linear transducer (MyLab Five; Hitachi Medical Corporation, Tokyo, Japan) to obtain short-axis views. The vein depth was measured from the skin surface to the top of the vein (Figure 1). The vein diameter was measured as the greatest dimension of the vein. A generous amount of ultrasonography gel was used to prevent contact between the transducer and skin surface only for measuring the diameter and the depth of the investigated veins by ultrasound.

Devices

Our prototype device was designed based on the reflection of NIR.[16] It comprises a light source (850-nm light-emitting diode) that may be transmitted through the subcutaneous tissue deeper than the light source of AccuVein for small absorption, compact infrared-sensitive charge-coupled device camera with
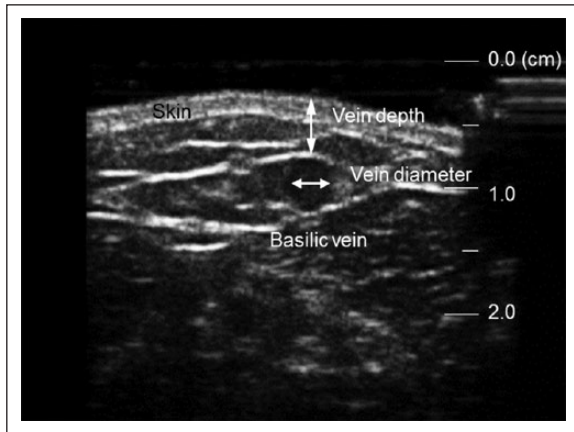
Figure 1. Transverse view of a basilic vein with ultrasound for the measurement of the vein depth and vein diameter.

video graphics array resolution (640×480), program-storage apparatus holding the image-processing instructions, and 4.1-in liquid crystal display, with a capture function to obtain still images. We adopted the most basic adaptive threshold methods for the enhancement effect of the running veins and the surrounding skin tissue on the local area needed catheterization. The device applies dynamic-threshold binary image processing to a moving near-infrared image.[11] The Niblack's method is based on the local mean, m, and standard deviation, $s(i, j)$, of gray values computed over a small neighborhood around each pixel in the form of

$$T(i, j) = m(i, j) + k \times s(i, j)$$

where k is the negative constant set to −0.2, and the local area was 15×15 pixels including target pixel. The experimental parameters were $k=0$, the lateral size of the local area was in "9," and the longitudinal size of the local area was in "15," emphasizing a contrast between vein and surround skin tissue and the vein running along a parallel trajectory on the longitudinal side. The benefits of the improved prototype device also include the compact main unit and display. The vascular image within the display appeared approximately 10 s from the time of turning the prototype on. The prototype device was used 15–20 cm above the investigated site. This distance would be possible to ensure a space needed to puncture the vein on the skin surface. The camera/display unit is stationary mounted on a flexible arm and a bottom slab with a necessary distance of freedom.

We compared the performance of our prototype device with that of AccuVein. We selected this device because it is the vein visualization device most commonly used in clinical practice. AccuVein utilizes the principle of reflection; a vascular image generated by laser light at a wavelength of 642 nm is projected over the puncture site itself. AccuVein was positioned 18–30 cm above the investigated site. This distance was recommended by the sales company.[17]

Evaluation of the visibility of investigated veins

A clinical research associate, who had worked at the facility for 5 years, assessed vein visibility by consecutively using the two-vein visualization devices to subjectively examine the investigated veins between the marker points on the skin (Figure 2). She used both devices on the investigated vein and rated vein visibility as visible, slightly visible, barely visible, and invisible. The visible or slightly visible veins were designated "visualized veins," whereas the barely visible or invisible veins were designated "nonvisualized veins." The invisible veins were not observed by the clinical research associate using avascularization alone, and the nonvisualized veins were not observed by the clinical research associate with avascularization and the prototype or the AccuVein. We decided to utilize two clinical research associates to classify approximately 25% of the veins to check inter-rater reliability with two ratings, that is, visualized veins versus nonvisualized veins.

Intensity ratio

The intensity ratio was measured via image analysis. The still vascular image for AccuVein was obtained by the clinical research associate using a digital camera (Caplio R7; Ricoh Co., Ltd, Tokyo, Japan) that was placed at the same position with AccuVein. The still vascular image for the prototype device was acquired by the clinical research associate using the capture function because we could not obtain appropriate still vascular images with a digital camera for over-reflection from the liquid crystal display. We uploaded both still images to a personal computer and converted different intensity data into identical intensity data; the analyzed area was a rectangular area containing the longitudinally centered investigated vein surrounded by skin tissue (Figure 3). We calculated the average reflected light intensity of the analyzed area in the lateral direction (Figure 4). The visualized vein shows a characteristic change as follows: a change in the average reflected light intensity of the analyzed area was considered to have changed "V," the lowest average reflected light intensity in the center of the lateral direction in the analyzed area, skyrocketing average reflected light intensity at each side of the lowest average reflected light intensity, generally continue to be flat, or exhibit a gradual downward trend after a sharp increase in the lowest average reflected intensity, with an R^2 value of polynomial approximation using the average reflected light intensity of ≥0.8 (order: 6). A nonvisualized vein did not show change like the visualized vein. We calculated the intensity ratio using the average reflected light intensity of the visualized veins. We considered the visualized veins to have high intensity ratios. The intensity ratio was calculated using the following equation
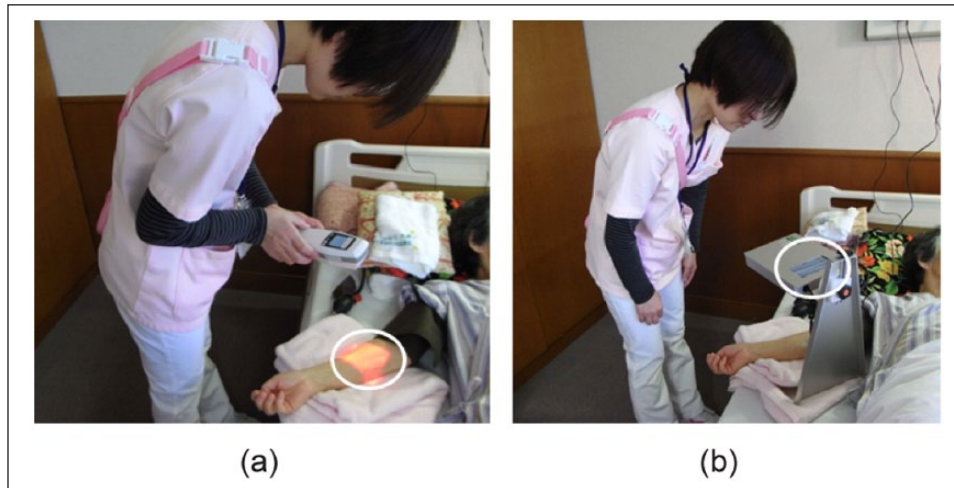
$$x = \frac{|a - b|}{|a + b|}$$

Figure 2. Subjective evaluation of venous images using the two devices: (a) AccuVein and (b) the prototype. Images inside the circle show the projected vascular images with each device. In our prototype, there are light-emitting diodes and a compact infrared-sensitive charge-coupled device camera under the liquid crystal display.
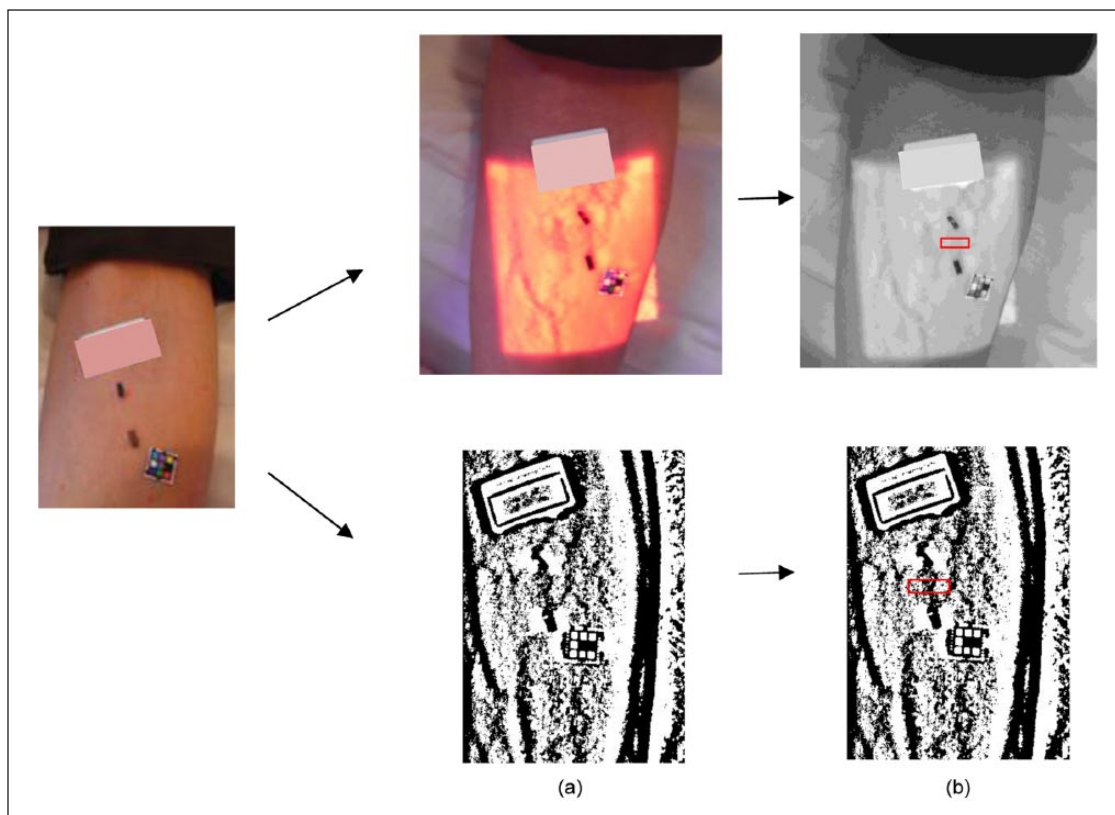

Figure 3. Selection of analyzed area for intensity ratio: (a) acquired image—we uploaded both still images to a personal computer and (b) infographic—next, we converted different intensity information into identical intensity information (8-bit value); the analyzed area was a $3 \times 5\,mm^2$ rectangular area containing the longitudinally centered investigated vein surrounded by skin tissue.

where a is the average reflected light intensity of the vein (i.e. the solid line of the average reflected light intensity with the lowest approximate curve in the center of the lateral direction assumed to represent the vein), and b is the average reflected light intensity of the skin tissue around the vein (i.e. the solid line of the average reflected intensity with the approximate curve assumed to represent subcutaneous tissue in the lower edges of the low-intensity line on the center of the lateral direction). The intensity ratios were only assigned to the visualized veins.
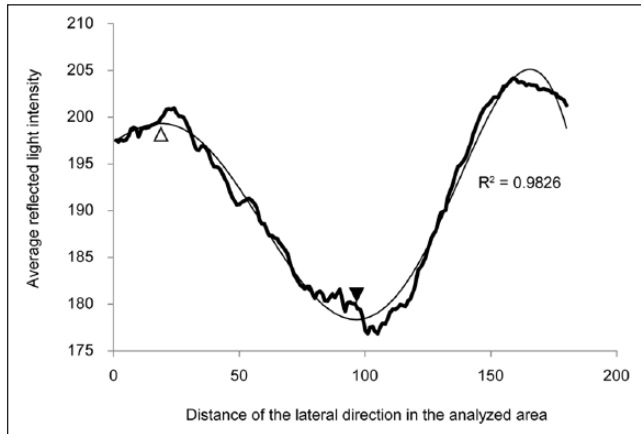
Figure 4. Changes in the average reflected light intensity of the analyzed area using the AccuVein®. Figure 4 is a graphical representation of the change in the average reflected intensity of the longitudinal analyzed area using the AccuVein (Figure 3). Black and white arrowheads indicate the average reflected light intensity of the veins and subcutaneous tissue, respectively. The black arrowhead, representing the vein, shows the lowest point near the center of the approximate curve of average reflected light intensity. The white arrowhead, representing the skin tissue surrounding the vein, shows the highest point of low elevation on the approximate curve of average reflected light intensity, while rising from the low-centered curve to the left and right edges. In this case, the left side is low, so the highest point on the left side is shown.

Statistical analysis

The primary end point was a comparison of the investigated vein visualization rate between the two devices using McNemar's test. A p-value of <0.05 was considered statistically significant. The secondary end point was a comparison of the variables of the visualized veins of the two devices using the Mann–Whitney U-test or chi-squared tests. Prior to this, we performed univariate analyses to extract candidate variables with significant differences between the visualized and nonvisualized veins for each device. The candidate variables may have no significant difference between the visualized and nonvisualized veins, and this was not adequate for comparing the visualized veins from each device. Variables with a p-value of <0.1 were considered to be high validity variables for comparing the visualized veins between devices. The software used for statistical analysis was JMP® 9.0 (SAS Institute Inc., Cary, NC, USA).

With an α of 0.05 and a power of 0.8, the estimated sample size for a two-sample comparison of visualization rates (AccuVein = 33.8%, prototype = 74.6%)[16] was 28 for each group.[18]

Results

Demographic data

We recruited a total of 101 eligible patients; of them, 72 were included in the analysis (Figure 5). Consequently, we directly analyzed 53 veins in the cubital fossa and 56 in the forearm. The median patient age was 73 years (interquartile range: 69–79 years), median body mass index (BMI) was 23.2 kg/m² (interquartile range: 21.2–26.2 kg/m²), and median hemoglobin value was 10.8 g/dL (interquartile range: 9.6–12.2 g/dL). According to their medical records, 50.0% (36/72) and 23.6% (17/72) of patients had musculoskeletal diseases and cancer, respectively.

The baseline characteristics of the invisible veins were similar between the investigated sites (Table 1). The median skin color a^* and the vein depth of the investigated sites differed. The most investigated vein in the cubital fossa was the median cubital vein, which is commonly used for blood collection. The median antebrachial vein, which is commonly used for venous catheter placement, was the most investigated vein in the forearm. Local illuminance ranged from 750 to 1200 lx.

Interrater reliability for subjective evaluation

Of the investigated veins, 27 (24.8%) consecutive veins were analyzed to test inter-rater reliability with two ratings (visualized veins versus nonvisualized veins). The inter-rater agreement (κ-value) was moderate for AccuVein (0.43; 95% confidence interval (CI), 0.01–0.85)) and good for the prototype (0.63; 95% CI, 0.17–0.95).

Comparison of visualization rates between devices

At the cubital fossa site, the visualization rate was 56.6% (30/53; 95% CI, 43.3%–69.0%) with AccuVein and 84.9% (45/53; 95% CI, 72.9%–92.1%) with the prototype; visualization rate was significantly higher with the prototype than with AccuVein ($p = 0.001$). At the forearm site, the visualization rate was 62.5% (35/56; 95% CI, 49.4%–74.0%) with AccuVein and 89.3% (50/56; 95% CI, 78.5%–95.0%) with the prototype; visualization rate was significantly higher with the prototype than with AccuVein ($p < 0.001$).

Comparison of visualized veins between devices

Tables 2 and 3 show the results of the univariate analysis of candidate variables for vein visibility for each device. Based on this analysis, the screen-detected candidate variables for assessing vein visibility were BMI, vein diameter, and vein depth. The results of the comparison of the visualized veins between devices (Table 4) showed that no significant differences were observed in the median BMI, vein depth, and vein diameter of the visualized veins at the cubital fossa and forearm sites.

At the cubital fossa site, the median intensity ratio of visualized veins with the prototype was significantly higher than that with AccuVein: 0.74 (interquartile range, 0.41–0.99) versus 0.03 (interquartile range, 0.01–0.05). At the
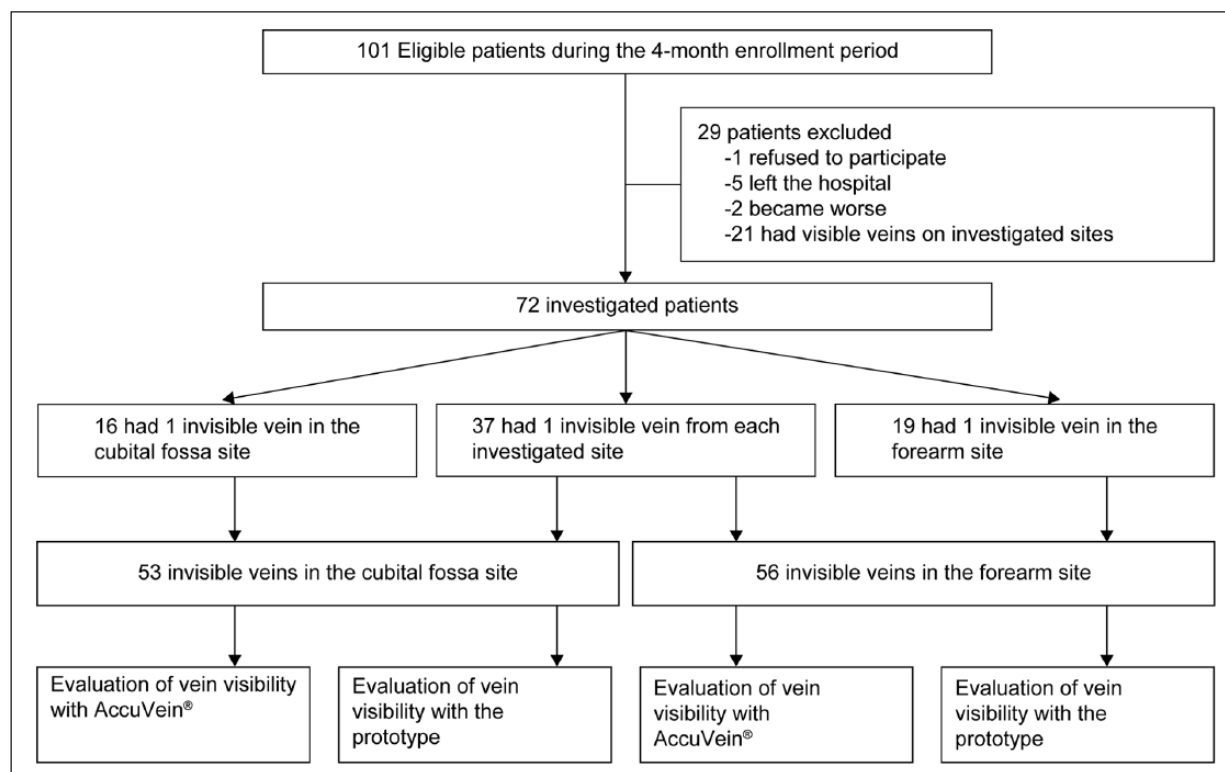
Figure 5. Flowchart of patient participation throughout the study.

Table 1. Baseline characteristics associated with invisible veins.

Invisible vein characteristics	Cubital fossa site (n = 53)	Forearm site (n = 56)	p
Median (interquartile range)			
Skin color L^*	55.35 (53.62–57.12)	55.68 (53.86–57.19)	0.764[a]
Skin color a^*	−0.04 (−2.33–3.81)	−1.82 (−3.74–1.02)	0.002[a]
Skin color b^*	8.23 (6.86–9.92)	8.27 (6.77–10.66)	0.792[a]
Diameter (mm)	2.6 (1.9–3.6)	2.6 (2.0–3.2)	0.711[a]
Depth (mm)	2.5 (2.1–3.5)	3.2 (2.2–4.5)	0.048[a]
Frequency (%)			<0.001[b]
Median cubital vein	27 (50.9)	1 (1.8)	
Median antebrachial vein	0 (0.0)	39 (69.6)	
Cephalic vein	16 (30.2)	12 (21.4)	
Basilic vein	10 (18.9)	4 (7.2)	

[a]Mann–Whitney *U*-test.
[b]Chi-squared test.

forearm site, the median intensity ratio of visualized veins with the prototype was significantly higher than that with AccuVein: 0.70 (interquartile range 0.54–0.85) versus 0.02 (interquartile range, 0.01–0.04) ($p < 0.001$ for both sites).

Discussion

In this study, we made two important clinical observations. First, the visualization rate obtained using the prototype device was approximately 90%, which was significantly higher than that obtained using AccuVein. Second, the vascular images captured by the prototype device had a greater intensity ratio between the vein and the surrounding skin tissue than those captured by AccuVein. These observations suggest that the prototype device is superior to AccuVein in terms of vein visualization in elderly patients. Our prototype should be tested for the percentage of success of actual blood draw, or IV attempts would be necessary for the invisible veins in elderly patients in the future.

Table 2. Evaluation of vein visibility using AccuVein®.

Investigated site	Variables	Visualized vein	Nonvisualized vein	p
Cubital fossa 50) ($n = 53$)	Frequency (%)			
	No. of veins	30 (56.6)	23 (43.4)	
	Male patients	14 (46.7)	10 (43.5)	0.817[a]
	Median (interquartile range)			
	Age (years)	73 (68–79)	71 (69–76)	0.666[b]
	BMI (kg/m^2)	23.1 (20.8–27.1)	23.4 (22.0–26.2)	0.584[b]
	Hemoglobin value (g/dL)	10.9 (9.3–11.9)	11.0 (9.9–12.8)	0.298[b]
	Diameter (mm)	2.8 (1.9–3.6)	2.6 (1.8–3.5)	0.666[b]
	Depth (mm)	2.3 (1.7–2.8)	3.4 (2.5–5.1)	<0.001[b]
	Skin color L^*	54.21 (53.47–56.46)	56.2 (53.82–57.89)	0.129[b]
	Skin color a^*	−0.07 (−2.45–3.00)	0.25 (−1.84–4.91)	0.667[b]
	Skin color b^*	8.11 (6.90–9.61)	8.58 (6.62–10.97)	0.501[b]
Forearm ($n = 56$)	Frequency (%)			
	No. of veins	35 (62.5)	21 (37.5)	
	Male patients	15 (42.9)	5 (23.8)	0.150[a]
	Median (interquartile range)			
	Age (years)	72 (70–79)	78 (69–82)	0.175[b]
	BMI (kg/m^2)	23.2 (21.7–25.7)	22.2 (20.5–24.8)	0.298[b]
	Hemoglobin value (g/dL)	11.5 (9.9–12.2)	10.6 (9.6–11.4)	0.160[b]
	Diameter (mm)	2.2 (2.0–3.1)	2.9 (2.5–3.3)	0.140[b]
	Depth (mm)	2.9 (2.1–3.9)	3.8 (2.2–4.7)	0.260[b]
	Skin color L^*	55.53 (53.00–56.93)	56.00 (54.09–57.99)	0.383[b]
	Skin color a^*kin co	−1.49 (−3.75–1.06)	−2.41 (−3.65–0.05)	0.966[b]
	Skin color b^*in	7.47 (5.96–10.12)	9.05 (7.77–10.90)	0.124[b]

BMI: body mass index.
[a]Chi-squared test.
[b]Mann–Whitney U-test.

The first point to be discussed is the difference of visualization rate with each device. The visualization rate of our prototype was similar to that reported by a previous study on AccuVein, VeinViewer (Christy Medical Corporation, Memphis, TN, USA) and VascuLuminator® (de Konigh Medical Systems, Arnhem, The Netherlands).[10] However, our results demonstrated a low rate of venous visualization with AccuVein. There are two possible reasons for this: first, all the veins investigated in this study were invisible; second, noise and artifacts captured by AccuVein hindered the subjective evaluation of vein visibility. One potential explanation is that the invisible veins are significantly deeper than the visible veins.[19] Before using a venous visualization device, it is important to make sure whether the investigated veins are visible or invisible. Previous studies do not accurately describe the visibility of the veins investigated. If some of the veins investigated in previous studies were visible before the use of a venous visualization device, it is possible that the veins we investigated were deeper. The challenge of using NIR is penetration depth; low-quality images are generated for deep veins.[20] We consider that our investigated veins were deep and, therefore, difficult to visualize with AccuVein. In this study, we did not detect a significant difference in the depth of the veins visualized by the two

devices. One reason may be that the invisible veins of elderly individuals have a narrower range because of a decrease in intercellular water and lower levels of intercellular lipids in their subcutaneous tissue.[21] Therefore, we consider it unlikely that the differences in visualization rate between the two devices resulted from differences in vein depth. Other potential explanations for the differences in visualization rate between the two devices are noise and artifacts captured by AccuVein. Using our prototype device, noise was present, but there were no artifacts. The artifacts and noise present in AccuVein images may have affected the subjective evaluation of vein visibility. The evaluator mentioned that it was difficult to distinguish whether the vascular images taken with AccuVein were really veins, and that vein location was hard to determine. This may have been affected by the method of image processing and skin texture.[22] Image-processing technology that reduces noise in vein image is likely to increase visualization ability.

Second, the vascular images captured by the prototype device had a greater intensity ratio between the vein and the surrounding skin tissue than those captured by AccuVein. We consider that the image-processing method used in this study appears to be more appropriate than that of AccuVein for subjectively visualizing invisible veins. A previous study

Table 3. Evaluation of vein visibility using the prototype.

Investigated site	Variables	Visualized vein	Nonvisualized vein	p
Cubital fossa ($n = 53$)	Frequency (%)			
	No. of veins	45 (84.9)	8 (15.1)	
	Male patients	20 (44.4)	4 (50.0)	0.771[a]
	Median (interquartile range)			
	Age (years)	73 (68–79)	71 (69–73)	0.237[b]
	BMI (kg/m^2)	23.0 (20.7–25.0)	27.4 (23.6–33.7)	0.006[b]
	Hemoglobin value (g/dL)	11.0 (9.6–12.4)	10.5 (9.6–11.7)	0.391[b]
	Diameter (mm)	2.6 (1.9–3.6)	3.0 (2.1–4.0)	0.397[b]
	Depth (mm)	2.5 (2.0–3.6)	5.4 (3.4–5.6)	0.001[b]
	Skin color L^*	55.33 (53.70–57.49)	55.83 (53.21–56.73)	0.619[b]
	Skin color a^*	0.46 (−2.14–3.81)	−1.31 (−2.68–4.83)	0.543[b]
	Skin color b^*	8.76 (6.87–10.12)	7.65 (6.67–8.83)	0.365[b]
Forearm ($n = 56$)	Frequency (%)			
	No. of veins	50 (89.3)	6 (10.7)	
	Male patients	18 (36.0)	2 (33.3)	0.896[a]
	Median (interquartile range)			
	Age (years)	75 (70–80)	70 (68–75)	0.117[b]
	BMI (kg/m^2)	23.1 (21.4–25.2)	21.6 (17.5–35.8)	0.389[b]
	Hemoglobin value (g/dL)	11.0 (9.6–12.3)	10.7 (10.1–11.0)	0.508[b]
	Diameter (mm)	2.4 (2.0–3.2)	3.1 (2.8–4.7)	0.039[b]
	Depth (mm)	3.1 (2.0–4.2)	4.6 (3.7–5.6)	0.021[b]
	Skin color L^*	55.67 (53.89–57.39)	56.00 (51.57–57.04)	0.947[b]
	Skin color a^*	−1.55 (−3.73–1.20)	−2.80 (−5.08–1.46)	0.185[b]
	Skin color b^*	8.07 (6.62–10.04)	10.06 (6.50–13.02)	0.321[b]

BMI: body mass index.
[a]Chi-squared test.
[b]Mann–Whitney U-test.

Table 4. Evaluation of vein visibility using the prototype.

Investigated site	Candidate variables	AccuVein® ($n = 30$)	Prototype ($n = 45$)	p
Cubital fossa	Median (interquartile range)			
	BMI	23.1 (20.8–27.1)	23.0 (20.7–25.0)	0.705
	Diameter (mm)	2.8 (1.9–3.6)	2.6 (1.9–3.6)	0.653
	Depth (mm)	2.3 (1.7–2.8)	2.5 (2.0–3.3)	0.182
	Intensity ratio	0.03 (0.01–0.05)	0.74 (0.41–0.99)	<0.001
Forearm	BMI	23.2 (21.7–25.7)	23.1 (21.4–25.2)	0.758
	Diameter (mm)	2.2 (2.0–3.1)	2.4 (2.0–3.2)	0.809
	Depth (mm)	2.9 (2.1–3.9)	3.1 (2.0–4.2)	0.989
	Intensity ratio	0.02 (0.01–0.04)	0.70 (0.54–0.85)	<0.001

BMI: body mass index.
Mann–Whitney U-test.

indicated that venous intensity differs according to device, and that AccuVein showed higher contrast than the other device.[9] However, this study did not mention the relationship between AccuVein intensity level and subjective evaluation. To enhance the images of veins and surrounding skin tissue acquired using NIR, an appropriate intensity level should be determined and low-quality images improved.[23] The relationship with subjective evaluation is an important element when setting an appropriate intensity ratio. The intensity ratio required for subjectively assessed "visible veins" is 0.01.

To achieve high venous visualization ability regardless of age, the visualization of deep veins and the ability to obtain vascular images with little noise must be improved. These are useful for successful peripheral venipuncture into the invisible vein.

This study has several limitations. First, we investigated only the characteristics of patients and veins; other factors that can affect vein visibility, such as the materials used in the devices (e.g. the polarizers) or the proper use of materials (e.g. light source position or high-brightness pulse irradiation), were not accounted for. Second, observer bias may have influenced the evaluation of vein visibility. Third, AccuVein lacks a function for capturing fluoroscopic images; therefore, vein images were captured with a digital camera. This may have affected the intensity ratio. However, we think that captured images with different cameras could not have a greater impact because all still images were converted into identical absolute intensity. Fourth, we only investigated participants from an Asian population. Finally, the visualization rate of devices needs to be investigated in further association with the percentage of success with actual IV access and locating time to vein.

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