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Does infrared visualization improve selection of venipuncture sites for indwelling needle at the forearm in second-year nursing students?

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ABSTRACT

Objectives: To evaluate the effectiveness of a vein visualization display system using near-infrared light ("Vein Display") for the safe and proper selection of venipuncture sites for indwelling needle placement in the forearm.
Methods: Ten second year nursing students were recruited to apply an indwelling needle line with and without Vein Display. Another ten participants were recruited from various faculty to serve as patients. The quality of the venipuncture procedure at various selected sites was evaluated according to a scale developed by the authors. Time, scores and patterns of puncture-site selection were compared with respect to three different methods: [1] attempt 1 (tourniquet only), [2] attempt 2 (Vein Display only) and [3] attempt 3 (both). To validate the effectiveness of Vein Display, 52 trials were conducted in total.
Results: We found that venipuncture site selection time was significantly improved with the Vein Display, particularly in the case of difficult to administer venipuncture sites. Overall, we found no significant difference with respect to venipuncture quality, as determined by our scale.
Conclusion: These results suggest that equipment such as the Vein Display can contribute immensely to the improvement of practical skills, such as venipuncture, especially in the context of elderly patients.
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Introduction

Throughout the world, human resource development and certification systems for advance practice nurses (APN) are becoming more common, with the United States leading the way. The increased attention being received by APN has been driven by and large by changing societal needs, particularly as it concerns changes in lifestyle and population aging (Collins-Bride and Saxe, 2013). Under this paradigm, the standard for nursing education has been transitioning to post-graduate master's programs and beyond (International Council of Nurses, 2002; American Association of College of Nursing, 2011). In Japan, the Certified Nurse Specialist (CNS) system was established in 1995. However it is widely acknowledged that Japan lags behind global standards, particularly with respect to the systems needed to support increased autonomy and expanded roles for nurses (Uchinuno, 2014; Tanaka, 2014). In order to catch up, the capacity of nursing education in Japan to teach advanced knowledge and skills must be improved, with particular emphasis on the transition-to-work system. Effective use of high function simulators has the potential to play a pivotal role in this regard, especially with respect to advanced skills training (Inoue, 2014).

Japan is currently undergoing a major social crisis, largely due to the accelerated aging of the Japanese population. To address this, the Japanese government instituted reforms at the turn of the millennium to provide long-term, home-based care to the increasing numbers of elderly patients (Horton, 2010). Hence, there is a demand for a shift to "community-oriented medical care" for providing comprehensive care supported with medical and nursing resources available in the community (Arai et al., 2015). The Long-Term Care Insurance system covers the long-term care of the elderly which was previously provided partly through the health insurance system and partly by the welfare measures for the elderly. National Institute of Population and Social Security Research reported the number of persons certified for the long-term care increased by more than 140% from 2000 (2.18 million) to 2013 (5.64 million). As a result, the number of patients requiring

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medical care services at home has been rapidly increasing, and is expected to increase demands for home-care nursing in the future (Asahara et al., 1999; National Institute of Population and Social Security Research, 2014). Accordingly, the demand for nurses capable of independently providing basic primary care has been increasing globally (Wang and Tsay, 2012).

Venipuncture is one of the most common clinical procedures in healthcare. However establishing peripheral intravenous access is challenging, particularly in pediatric and geriatric patients with fragile or hidden veins. Insufficient venipuncture skills or difficult intravenous access results in the need for multiple needle insertion. Failure rates are reported to occur in 30–50% in difficult patients (Walsh, 2008).

Multiple venipuncture attempts are associated with an increased incidence of extravasation, vascular perforation causing hematoma or hemorrhage, and phlebitis. This not only heightens patient anxiety and suffering, but failed attempts can also compromise the trust and confidence a patient has in the nursing staff (Walsh, 2008).

Until the Japanese government changed the guidelines regarding venipuncture by nurses in 2002, it was clearly defined that venipuncture was beyond the scope of practice for registered nurses. Since then, there have been many recommendations regarding appropriate protocols for making clinical venipuncture a part of nursing education in Japan. This has also partly been driven by calls for increased clinical cost efficiencies and governmental regulation. In 2003, the Japanese Nursing Association released the Guidelines for the Practice of Venipuncture, which defined four practical levels of venipuncture by nurses. In accordance with the Guidelines, each hospital has been actively responding by developing programs for venipuncture and fluid infusion management.

This, however, hasn't come without its challenges.Across the globe, nursing education has been compelled to focus increasingly on practical skills and knowledge, such as those necessary for safe and proper venipuncture. A 2012 review reported numerous cases of peripheral nerve injuries due to improper venipuncture (Stevens et al., 2012). And since then, numerous other reports have emerged describing the severity of this problem (Ramos, 2014). Based on these statistics alone, however, the magnitude of this issue is very likely to have been underestimated (Moore and Stringer, 2012). Indeed, within the US alone, venipuncture has been reported to be the number one cause of injury among patients (Walsh, 2008). This reality has lead to many efforts to identify optimal venipuncture technique (Parisotto et al., 2014). In addition, there have been many reports on the development of various tools and methods for improving the success rate of venipuncture, in practice (Balter et al., 2015; Juric et al., 2014). Such issues are also relevant to nursing practice and education in Japan, where a review of the Japanese literature (Takahashi et al., 2011, 2013) and (Sugama, 2012) consistently demonstrated that creative interventions like the use of equipment to show subcutaneous vessels and nerves, are a necessity, especially for novice learners. This is especially true in cases requiring specialized care, such as with elderly or pediatric patients, whose veins are often difficulty to palpate, or patients who are obese or darker-skinned, whose veins are difficult to identify (Walsh, 2008).

It has been demonstrated that improved training and education reduces the rate of error when performing venipuncture, in practice (Lima-Oliveira et al., 2012). However, in Japan, nurses are not allowed to practice on humans until they have become licensed, and so the present curriculum for undergraduate nursing doesn't include live venipuncture training. For example, at our university, second year nursing students are obliged to take the course “Nursing Procedure III”, which includes lectures (90–135 min each) and practical sessions (135 min × 2 times) for venipuncture. This course uses a type of simulator model for the forearm; however, the simulator is not realistic in some areas; for example, there is no effect on applying or removing a tourniquet. Consequently, nursing students can not experience the engorgement of blood vessels and bleeding upon removal of the needle. For that reason, it is vitally important for instructors to check that students carried out the procedure precisely as instructed. To address this, we are consistently searching for new methods or technologies to improve the quality of venipuncture education, given the practical limitations here in Japan.

To this end, we were recently given a chance to test-out a new vein visualization display system (tentatively referred to as “Vein Display”) that uses near-infrared light for displaying subcutaneous veins. Numerous recent studies have demonstrated the effectiveness of various techniques or technologies to improve vein visualization. The oldest such technique is referred to as transillumination and involves the placement of light sources under or around an extremity (John, 2007). More recently, ultrasound, which is becoming increasingly recommended in central venous catheter placement (Karakitsos et al., 2006), has been increasingly demonstrated to improve peripheral venipuncture success under various circumstances (Brannam et al., 2004; Schnadower et al., 2007). Near-infrared visualization is a more recent addition and involves the direct illumination and visualization of the venipuncture site. It is regarded as one of the most promising methods for improved venipuncture success rates, due to improved vein identification times, fewer number of required attempts, and shorter time for IV placement (Juric et al., 2014). It has also been noted to be effective for patients who veins are typically difficult to palpate or identify (de Graaff et al., 2013; Cuper et al., 2012).

The purpose of this study was to evaluate the effectiveness of the Vein Display for the selection of venipuncture sites for indwelling needle placement in the forearm, in the context of a clinical skills training program for second year nurses. This paper describes the effectiveness of the Vein Display technology for enhancing learning for novice students and extends current knowledge regarding the application of this technology in nursing education, to ensure the provision safe and precise care of patients in an increasingly aging society.

Methods

Subjects

Ten participants were recruited from among 80 second year nursing students to apply an indwelling needle line with and without infrared visualization (implementation subjects). Another ten participants (5 males and 5 females) were recruited from various faculty across Mie University (age 20–38, 24.9 ± 5.5 y.o.) to serve as patients (patient's-role subjects) (Table 1). Both the 10

Table 1
Age and sex of the patient's role subjects (n = 10).

Patient's role subjects	Age	Sex
A	22	Male
B	26	Female
C	30	Male
D	22	Male
E	21	Male
F	26	Female
G	38	Male
H	20	Female
I	21	Female
J	23	Female

implementation subjects and the 10 patient's-role subjects provided signed consent to participate in this study.

The participants received no special instruction or training in venipuncture procedure, outside of the regular curriculum training already described.

Measurements

The quality of the venipuncture procedure at various selected sites was evaluated according to a scale developed by the authors based on previous studies (Table 2). In addition, for each procedure, we measured elapsed time from start to venipuncture site selection.

Prior to this study, no suitable scale or criteria for vein selection at the forearm had been reported. Therefore, the authors developed a 3-point scale based on the following 4 adverse criteria: 1) meandering site of the vein, 2) branching site of the vein (Shima et al., 1990; Mikuni et al., 2013), 3) near the common site of cutaneous nerve (Yamada et al., 2008; Kimori et al., 2010; Gomi, 2012), and 4) less than 4 cm from the cubital crease or the most distal crease of the wrist (Robson et al., 2008; Samarakoon et al., 2011; Kim et al., 2014). In order to maximize butterfly needle safety even during joint motion, the following 3 levels were evaluated: "yes" meant the site selected represented a clear risk and was scored as 0, "ambiguous" meant the site selected represented a potential risk and was scored as 1, and "no" meant free from any risk and was scored as 2. The total possible score ranged from 8 (highest) to 0 (zero), except in the case of "extravascular" site selection (defined as site selection more than 2 mm away from the target vein), which was not scored, regardless of any other criteria (Table 2).

Equipment

Specifications for the Vein Display (Sharp Co. Ltd.):

The Vein Display (Sharp Co. Ltd.) consists of a CMOS camera that is sensitive to infrared light (1280 × 1024 pixels resolution, monochrome), an infrared light-emitting diode lighting (wavelength of 940 nm), image processing system, and display. The visualization process of the Vein Display is as follows: first, the surface of the skin is exposed to infrared light; next, an image of the illuminated portion is taken by a camera mounted on the system. The image obtained is shown on the display and enhanced via image processing; and to ensure less-visible venipuncture sites are displayed properly, the image is continuously sampled and processed frame-by-frame. In addition to these features, the Vein Display's advanced processing capabilities and operational flexibility make it easy to confirm appropriate venipuncture sites across an entire forearm or to enlarge an image of tiny blood vessels such as those in the fingertips.

The video equipment used to record all sessions consisted of a home video recorder (SONY HDR-SR11) on a tripod at each of 3 booths.

Procedure

We set-up 3 booths in a large practice room to precisely evaluate whether the sites selected by the implementation subjects were consistent with safe and appropriate venipuncture, as defined by our scale. Each booth had 3 or 4 patient-role subjects respectively, a resting space for the patient-role subjects, 1 time-keeper, 1 operator for the devices, video equipment to record the proceedings, and the "Vein Display", which also functions as a still camera. All implementation subjects were directed to rotate to every booth according to the time schedule and the time-keepers' instructions. In total, each implementation subject participated in 10 trials, with 10 different patient-role subjects, consisting of 3 attempts each. Each of the three attempts were made in succession, after which the implementation subject would move on conduct the trail, once again, with the next awaiting patient-role subject. The protocol employed was as follows:

(1) Implementation subjects

[1] Selection of a suitable venipuncture site: attempt 1 (with a tourniquet only)

First, implementation subjects were directed to apply a tourniquet to the left forearm of one of the patient-role subjects and then to mark the site determined most suitable within 30 s by using an arrow-head-shaped sticky note. Subjects were not allowed to see the screen of the "Vein Display", as its surface was covered. However, the "Vein Display" was used to capture still images of the venipuncture selection site; these were later evaluated by three of the authors (K.F., Y.N., and Y.T.) as print-outs after the session.

[2] Selection of a suitable venipuncture site: attempt 2 (with Vein Display only)

For the next attempt, the implementation subjects were directed to select a suitable venipuncture site using the "Vein Display", without the aid of a tourniquet. They were then asked to mark the site determined most suitable within 30 s using an arrow-head-shaped sticky. Still pictures of the venipuncture selection site were taken using "Vein Display", and evaluated similarly to the first round.

[3] Selection of a suitable venipuncture site: attempt 3 (with both a tourniquet and Vein Display)

As the final attempt, the implementation subjects were directed to select a suitable venipuncture site using the "Vein Display", after having applied a tourniquet to the same arm once again. They were once again asked to mark the site determined most suitable within 30 s using

Table 2
Vein selection score to keep a butterfly needle safely at the forearm.

	Item	Score		
		Yes	Ambiguous	No
1	Meandering site of the vein	0	1	2
2	Branching site of the vein	0	1	2
3	Near the common site of cutaneous nerve	0	1	2
4	Less than 4 cm from the cubital crease or the most distal crease of the wrist	0	1	2
*	Extravascular: (site selection of more than 2 mm from blood vessels on the image)	not scored		

Highest score 8.
Lowest score 0, *except for the selection of extravascular.

an arrow-head-shaped sticky note. Once again, still pictures of the venipuncture selection site were taken using "Vein Display", and evaluated similarly to the previous rounds.

(2) Patient-role subjects

The patient-role subjects waited for their respective turns at the designated resting space. They were instructed to roll the left sleeve up to the arm and to report to the designated booth according to their turn. It took less than 10 min for each patient-role subject's turn and they waited in the resting space until the next scheduled turn.

(3) Supporting staff

[1] Director

One of the authors (K.F.) acted as director of the study, which included confirming the state of preparation, calling the start of the evaluation process for the 1st implementation subject, and calling completion.

[2] Time-keepers

Every time-keeper was a member of the department of nursing faculty. Time-keepers were tasked with checking the time schedule at each booth and recording the elapsed time from the beginning of site selection, in the event that the video failed to record. The starting time was set just as the tourniquet was applied, as opposed to the time of its inflation. The time-keepers also provided direction to the subjects, as necessary.

[3] Operators for devices

The operator of the devices mainly managed the operation of the "Vein Display", which included: putting on and removing the cover, taking still pictures as needed, and adjusting video settings, as necessary.

(4) Data preparation

We reviewed a total of 100 sets of images taken by the Vein Display to identify patterns in venipuncture site selection and scored them according to the predetermined scale (Table 2) (Fig. 1). Next, 3 of the authors (K.F., Y.N., and Y.T.) reviewed the video from this study and measured the selection time as previously defined; the selection time was then recorded as the average of the three measurements.

The pattern of puncture-site selection for each implementation subject was recorded after we checked the selected puncture-sites on the images recorded using the Vein Display infrared visualization system, according to the criteria previously described (Table 3). For example: "Code I" indicates the same site-selection from attempt 1 to attempt 3. "Code II" indicates that the implementation subject first selected a site on attempt 1, but then selected another site on attempt 2 and kept the same site for attempt 3. "Code III" indicates that the student selected different sites at every step. Meanwhile, "Code IV" indicates that the student first selected a site on attempt 1, then selected another site on attempt 2, and then returned to the initial site on attempt 3. Overall, we determined 9 patterns from "Code I" to "Code IX", with an "x" indicating extravascular selection.

Fig. 1. Shot image: Left forearm.

Table 3
Criteria of the pattern of selection (classified into 9 codes).

Pattern of selection			Code
Attempt 1	Attempt 2	Attempt 3	
a	a	a	I
a	b	b	II
a	b	c	III
a	b	a	IV
a	a	b	V
x	a	a	VI
a	B	x	VII
a	X	b	VIII
x	X	x	IX

x: in case of extravascular selection.

(5) Data analysis

To test the significance of the differences, we used a non-parametric Kruskal Wallis Test for comparison of score and selection time between groups (patient-role subjects, implementation subjects), and Friedman's Test for comparison of score and selection time between the three different methods. For the analysis, SPSS Ver.20.0 was used and the significance level was set at <5%.

(6) Ethical considerations

At no point in this study were participants subject to harm, either via physical venipuncture or due to tourniquet application. In order to further ensure the comfort and safety of participants, we placed an upper time limit of 30 s on tourniquet application. The participants were provided written consent forms by one of the authors (K.F.) with information about the purpose of this study, anonymity of the data, the protection of privacy, the safety of the participants, and the appropriate way to withdraw from this study.

Participants were given additional guarantees that participation would have no bearing on academic evaluation. The study was approved by the Research Ethics Committee of the School of Medicine, University of Mie, Mie, Japan (No. 2663).

Results

Time of puncture-site selection

There were no significant differences found in the selection times for each of the venipuncture sites with respect to the three different methods, for all patient-role subjects save one: subject "I". For this patient, the average time for puncture site selection for attempt 1 was significantly longer (Table 4).

As for the implementation subjects, in general, no significant differences were found in selection times with respect to the 3 selection methods (Table 4). However, in the case of implementation subject "No. 2", the puncture site selection time using only the Vein Display (attempt 2) was longer than with the other attempts. On the other hand, for"No. 9", we found the puncture site selection time using only the Vein Display (attempt 2) to be lower (Table 5).

Table 4
Selection time: patient's role subject.

Method of selection		Mean (SD)									
		Selection time: patient's role subjects (second)									
		A	B	C	D	E	F	G	H	I	J
	p value	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	**0.003	n.s.
Attempt 1: only tourniquet	**0.000	19.9 (5.8)	15.9 (6.0)	12.1 (3.2)	19.2 (8.4)	17.6 (5.7)	13.8 (7.0)	14.5 (6.0)	13.5 (5.7)	31.4 (14.0)	10.2 (3.8)
Attempt 2: only Vein Display	*0.036	20.3 (11.4)	20.2 (12.2)	14.9 (5.0)	20.3 (9.8)	17.4 (8.2)	12.0 (6.2)	29.3 (33.1)	14.2 (3.9)	16.4 (6.6)	11.3 (3.7)
Attempt 3: Vein Display and tourniquet	*0.049	19.3 (6.9)	19.0 (7.0)	15.6 (6.3)	18.7 (7.1)	14.1 (4.1)	13.5 (5.9)	15.2 (3.9)	12.8 (12.8)	21.0 (6.2)	15.5 (7.0)

*p < 0.05; **p < 0.01.

Table 5
Selection time: implementation subject.

Method of selection		Mean (SD)									
		Selection time: implementation subject (second)									
		1	2	3	4	5	6	7	8	9	10
	p value	n.s.	*0.019	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*0.035	n.s.
Attempt 1: with a tourniquet only	**0.006	10.0 (3.7)	19.8 (6.0)	13.9 (5.9)	17.7 (7.3)	16.2 (7.1)	19.5 (9.3)	17.3 (7.1)	13.9 (12.5)	19.2 (15.5)	20.5 (6.0)
Attempt 2: with Vein Display only	**0.000	10.1 (4.1)	22.0 (35.2)	17.1 (5.2)	19.5 (5.0)	18.9 (5.9)	18.8 (5.8)	14.3 (4.3)	11.8 (4.2)	14.3 (5.8)	28.5 (14.8)
Attempt 3: with both	*0.011	12.3 (6.6)	15.3 (7.5)	19.0 (7.0)	16.5 (4.5)	14.9 (4.8)	16.2 (5.9)	14.3 (4.0)	14.8 (5.8)	17.4 (3.7)	23.3 (6.8)

*p < 0.05; **p < 0.01.

Overall, however, significant differences were found with respect to average puncture site selection time for each of the three different selection methods (Table 6–8), albeit only when analyzed in the aggregate.

Scores of puncture-site selection among 3 attempts

Regarding each of the three attempts, there was no significant difference in puncture-site selection scores according to our scale, with respect to either patient-role subjects or implementation subjects (Table 9 and Table 10).

Patterns of puncture-site selection

For attempts 1 through 3, about one third (35%) of the implementation subjects selected the same site each time ("Code I") (Table 11). The second most frequent pattern was "Code III" (26%), while the third most frequent was "Code II" (17%) (Table 11). Overall, about half (52%) of all trials resulted in a different site selection between attempts 1 and 3.

We also examined differences between patient-role subjects, with respect to implementation subjects' site selection performance. For example, in patient-role subjects "F" and "J", 80% of the implementation subjects selected the same pattern ("Code I") (Table 12). Meanwhile, in patient-role subject "I", 40% of implementation subjects made extravascular selections ("Code VII", "Code VIII", and "Code IX") (Table 12).

Between attempts 1 and 3, score changes were found in 17 cases (32.7%), while the same score was shown in 22 cases (42.3%) (Table 12). For an increased score, this is shown as a superscript asterisk on the margin of the code, which a decreased score is shown as a subscript asterisk on the footer of the code (Table 12).

Selection of sites close to vein bifurcation was the most frequent reason for decreased site selection scores in this study. Overall, the factors associated with decreased site selection scores were: 1) nearness to meandering of the vein in 3 cases (25%), 2) close to vein bifurcation in 9 cases (69.2%), and 3) near the joint in one case (7.7%). None selected 4) a site that increased the likelihood of nerve damage (Table 13).

Table 6
Selection time: attempt 1 (with a tourniquet only).

Implementation subjects		Selection time (second)									
		Patients' role subjects									
		A	B	C	D	E	F	G	H	I	J
	[mean (SD)] p value **0.000	19.9 (5.8)	15.9 (6.0)	12.1 (3.2)	19.2 (8.4)	17.6 (5.7)	13.8 (7.0)	14.5 (6.0)	13.5 (5.7)	31.4 (14.0)	10.2 (3.8)
	**0.006										
1	10.0 (3.7)	11	14	9	11	16	5	7	8	13	7
2	19.8 (6.0)	29	14	13	18	16	16	24	23	29	16
3	13.9 (5.9)	18	13	15	17	22	13	7	9	21	4
4	17.7 (7.3)	25	25	7	11	21	13	14	20	29	12
5	16.2 (7.1)	25	9	11	14	18	7	18	20	29	11
6	19.5 (9.3)	21	17	10	35	24	24	10	11	32	11
7	17.3 (7.1)	24	13	14	24	21	12	13	15	30	7
8	13.9 (12.5)	13	8	10	14	8	9	11	10	49	7
9	19.2 (15.5)	17	23	15	16	8	12	20	7	61	13
10	20.5 (6.1)	16	23	17	32	22	27	21	12	21	14

*p < 0.05; **p < 0.01.

Table 7
Selection time: attempt 2 (with a Vein Display only).

Implementation subjects		Selection time (second)									
		Patients' role subjects									
		A	B	C	D	E	F	G	H	I	J
	[mean (SD)] p value *0.036	20.3 (11.4)	20.2 (12.2)	14.9 (5.0)	19.2 (9.9)	17.4 (8.2)	12.0 (6.2)	29.3 (33.1)	14.2 (3.9)	16.4 (6.6)	11.3 (3.7)
	**0.000										
1	10.0 (3.9)	11	18	8	9	10	4	8	14	7	11
2	22.0 (35.2)	13	13	13	6	10	9	122	12	11	11
3	17.1 (5.2)	15	22	12	20	26	15	13	23	14	11
4	19.5 (5.0)	17	20	24	18	20	25	24	11	24	12
5	18.8 (5.8)	24	12	17	25	27	17	14	17	24	11
6	18.9 (5.9)	21	14	14	24	25	11	27	15	24	14
7	14.3 (4.3)	18	19	15	17	10	12	21	11	12	8
8	11.8 (4.2)	16	10	9	16	9	7	19	15	9	8
9	14.3 (5.8)	17	21	21	15	10	6	19	9	18	7
10	28.5 (14.8)	51	53	16	42	27	14	26	15	21	20

*p < 0.05; **p < 0.01.

Table 8
Selection time: attempt 3 (with both).

Implementation subjects		Selection time (second)									
		Patients' role subjects									
		A	B	C	D	E	F	G	H	I	J
	[mean (SD)] p value *0.049	16.4 (6.9)	19 (7.0)	15.6 (6.3)	17.9 (7.2)	14.1 (4.1)	13.5 (5.9)	15.2 (3.9)	12.8 (2.6)	21.0 (6.2)	15.5 (7.0)
	*0.011										
1	12.2 (6.2)	21	11	26	11	9	8	10	8	11	7
2	15.3 (7.5)	13	26	9	8	10	13	16	14	31	13
3	19.0 (7.0)	32	28	15	15	21	11	11	15	19	23
4	16.5 (4.5)	21	25	15	16	14	10	12	14	18	20
5	16.2 (5.9)	13	15	10	24	12	18	18	13	28	11
6	14.9 (4.8)	24	12	8	15	12	12	20	11	18	17
7	14.3 (4.0)	16	15	17	23	14	12	11	9	15	11
8	14.8 (5.8)	9	10	25	18	12	7	17	15	22	13
9	17.4 (3.7)	18	23	19	16	16	17	20	14	21	10
10	23.3 (6.8)	26	25	12	33	21	27	17	15	27	30

*p < 0.05; **p < 0.01.

Table 9
Average scores by vein selection criteria (see Table 2): patient's role subjects.

Mean (SD)											
Method of selection	p value	Vein selection score: patient's role subjects									
		A	B	C	D	E	F	G	H	I	J
Attempt 1:with a tourniquet only	**0.036	7.2 (1.0)	7.2 (1.0)	7.0 (1.1)	5.8 (2.0)	7.0 (1.0)	8.0 (0)	6.6 (1.0)	7.1 (1.0)	7.4 (1.0)	7.7 (0.7)
Attempt 2:with Vein Display only	**0.000	7.0 (0.9)	7.0 (1.1)	6.6 (1.0)	5.8 (1.5)	7.7 (0.7)	8.0 (0)	6.4 (0.8)	7.8 (0.4)	7.1 (1.1)	7.7 (0.7)
Attempt 3:with both	n.s.	6.9 (1.0)	7.2 (1.0)	7.0 (1.1)	7.1 (1.4)	7.3 (0.9)	7.8 (0.6)	6.8 (1.0)	7.6 (0.8)	6.9 (1.1)	7.9 (0.3)

*p < 0.05, **p < 0.01.

Table 10
Average scores by vein selection criteria (see Table 2): implementation subject.

Mean (SD)											
Method of selection	p value	Vein selection score: Implementation subject									
		1	2	3	4	5	6	7	8	9	10
Attempt 1:with a tourniquet only	n.s.	7.2 (1.0)	7.1 (1.4)	7.0 (1.5)	7.2 (1.4)	7.3 (1.0)	6.4 (1.3)	7.6 (0.9)	6.6 (1.4)	7.7 (0.7)	6.9 (1.0)
Attempt 2:with Vein Display only		7.8 (0.6)	6.7 (1.3)	7.3 (1.0)	7.6 (0.8)	7.1 (1.4)	6.6 (1.0)	7.1 (1.1)	7.1 (1.0)	7.3 (0.9)	6.5 (1.3)
Attempt 3:with both		7.6 (0.9)	7.1 (1.3)	7.5 (0.9)	7.4 (1.0)	7.6 (0.9)	7.0 (1.1)	7.3 (0.9)	7.4 (1.0)	7.2 (1.0)	6.6 (1.0)

*p < 0.05, **p < 0.01.

Table 11
Percentage of pattern of selection (distribution of 9 codes).

Pattern of selection			Code	%
Attempt 1	Attempt 2	Attempt 3		
a	a	a	I	35
a	b	b	II	17
a	b	c	III	26
a	b	a	IV	9
a	a	b	V	8
x	a	a	VI	1
a	b	x	VII	1
a	x	b	VIII	1
x	x	x	IX	2

x: in case of extravascular selection.

Table 12
Score change from attempt 1 to attempt 3.

Implementation subjects	Patient's role subjects, pattern of selection, score change from attempt 1 to attempt 3									
	A	B	C	D	E	F	G	H	I	J
1	II*	I	I	II	V	I	III	III*	VII	I
2	I*	III	IV	I	II*	I	III	I	I	I
3	III	I	II	III*	VI	I	I	I	IX	I
4	III	IV	III*	III*	IV*	I	I*	I	III	I
5	III*	I	I	IV	II*	I	III*	III*	IX	I
6	II	II	I	III*	V*	I	III	II*	II*	I
7	IV	III	V*	III*	V*	II*	IV	IV	VIII*	IV
8	I	I	V*	III*	III*	I	IV	II	II	I
9	II*	V	III	III	III*	I	I	I	III*	I
10	II	V	II*	III*	II*	II	III*	I*	III	V*

Invalid from VI to IX due to extravascular selection.
An asterisk position shows increase x* (superscripted), same x (no asterisk) and decrease x* (subscripted).

Discussion

The purpose of this study was to evaluate the effectiveness of the Vein Display (Sharp Co. Ltd.) infrared visualization system for the selection of venipuncture sites for indwelling needle placement in the forearm, in second-year nursing students. Time, scores and patterns of puncture-site selection were compared with respect to three different methods. We now discuss our findings.

Selection time of venipuncture sites

In patient-role subject "I", it consistently took longer for the implementation subjects to select the puncture sites using the usual tourniquet only method. However, site selection took significantly less time when the Vein Display infrared visualization system was used. Thus, we were able to confirm the effectiveness of the Vein Display infrared visualization system in a subject whose veins were demonstrably difficult to identify. Based on this finding, we feel the Vein Display infrared visualization system may generally be more helpful when used in cases where the blood vessel may be difficult to find, for example the obese, or the elderly.

On reflection, we believe that the selection of puncture sites may have been relatively easy due to the good health and youth of the patient-role subjects in this trial (the average age: 24.9 ± 5.5 y.o.). In other words, we feel the easily palpable veins of such young subjects may have been responsible for the lack of a significant reduction in the selection time of puncture sites. In all cases, the Vein Display presented substantially more visible information and provided more choices for site selection than would have been possible without the equipment.

Vein selection scores across 3 attempts

Prior to this study, we could not find any suitable scale or criteria on vessel selection at the forearm. Therefore, the authors needed to create a scale and pattern criteria, as shown in Tables 2 and 3, that could reliably be used to convert all 100 sets of images of images into usable scores. We found that selection time was shorter than we had expected before the study. The reason may have been due to the fact that our implementation subjects were not actually placing a needle into the skin of a live patient. There were some cases of inadequate tourniquet fitting procedures, however it did not appear to influence implementation students' scores.

On the other hand, we found significant differences between attempts 1 and 2 with respect to vein selection scores among patient-role subjects. In clinical practice, the assessment by palpation of the size, hardness, elastic force, and direction of each blood vessel influences the decision as to which puncture site to select. In this study, we did not examine the method by which these novice students determine the puncture site. As a result, we feel that future studies will require a modified scale for beginning students, as well as additional clarification of the evaluation process for subjects' assessment of blood vessels. Regarding the three different patterns observed for the puncture site selection, 52 trials resulted in different sites in the attempts 1 and 3. Of these, 39 resulted in equal or better venipuncture, as determined by our scale. These results suggest that the Vein Display infrared visualization system may have indeed provided a more efficient means to find the selection site, for these novice students. Meanwhile, the remaining 13 trials resulted in decreased scores. Based on our observations, we think that the enhanced visual information using Vein Display may have confused some novice students and caused them to misjudge the venipuncture selection site, especially in cases where the blood vessels were easily identifiable, even without benefit of the Vein Display.

In this study, the scale item "branching site of the vein (vessel bifurcation)" constituted the most common cause of decreased scores (67% of all such cases). We set up briefings one week prior to this research, in order that nurses could carry out a review of intravenous injection skills. In addition, we provided another review immediately prior to the study, with additional precaution about the selection of blood vessels for venipuncture. Some students nevertheless misjudged the selection site, resulting in the relatively common occurrence of "vessel bifurcation" even with the Vein Display. Based on our observations, it seemed very difficult for novice students to identify a suitable venipuncture site in the case of non-palpable vessel bifurcation. We suspect this is due to their

Table 13
Reason for the decrease in score.

		n = 13	%
1	Meandering site of the vein	3	23.1
2	Branching site of the vein	9	69.2
3	Near the common site of cutaneous nerve	0	0
4	Less than 4 cm from the cubital crease or the most distal crease of the wrist	1	7.7

having had no prior experience practicing this procedure on live persons. In this regard, we feel we need to take special care, especially with novice students who may have over-simplified imaginations about the proper way to puncture with an indwelling needle. Thus, we feel that a device that provides realistic practical lessons will improve students' understanding and knowledge, as future practitioners.

Our research findings are corroborated by previous reports showing that near-infrared visualization technology (like the Vein Display) improves venipuncture vein identification times (Hess. 2010; Cuper et al., 2012; Sun et al., 2013). Furthermore, we were able to confirm the effectiveness of the Vein Display for locating difficult to identify veins, among nursing students. This is consistent with previous research demonstrating the effectiveness of similar visualization technology in support of nursing practice (Perry et al., 2011), and lends further support to our conclusions regarding the effectiveness of this technology in nursing education.

The IOM 2010 Report "The Future of Nursing: Leading Change, Advancing Health" promotes the improvement of nursing skills and education systems. According to these recommendations, nurses must "achieve higher levels of education and training through an improved education system that promotes seamless academic progression" and "practice to the full extent of their education and training". The present study represents a step towards these goals. In the future, we expect technology such as the Vein Display to help ensure a comfortable and safe learning environment for nursing and medical students, while ensuring they master the skills needed for clinical practice. Further developments of this technology to ensure accessibility and ease of use will help to ensure the highest standards of patient safety and care, and better outcomes for patients across the globe.

We initially placed an upper limit of 30 s on tourniquet application, to ensure the safety and comfort of all participants. However, as this was exploratory research, we allowed this limit to be exceeded as long as application fell within Japanese Association of Medical Technologists guidelines, which recommend an upper limit of 60 s. In one case, where tourniquet application exceeded this limit, we determined, according to our medical judgement, that continued application posed no harm to the participant. Following the procedure, we conducted a brief physical examination to confirm the subject's well-being.

Limitation of this study and future directions

The limitations of this study were as follows: 1) small number of subjects (only 10 by 10), 2) lack of any suitable pre-existing scale for evaluation, and 3) possible ambiguities due to the newness of the device.

One of our future challenges is to clarify how Vein Display can be most effectively put to use in our students' education. Longitudinal studies following participants in this study (sophomores at the school of nursing) may be one possible choice. In addition, modification of the scale, as previously discussed, may also be considered.

Conclusions

We evaluated the effectiveness of the Vein Display (Sharp Co. Ltd.) infrared visualization system for the selection of venipuncture sites for indwelling needle placement in the forearm in second-year nursing students. The equipment had clear benefits. Venipuncture site selection time was improved significantly and consistently. Moreover, these results suggest that infrared visualization equipment, such as the Vein Display, can improve the quality of venipuncture in patients whose veins are difficult to palpate, as is often the case with elderly patients. This is especially relevant in Japan, where social and demographic realities require that we improve our systems for home and primary medical care within the context of community healthcare, in addition to supporting expansion of the home-visit nursing care service. In such cases, nurses often bear sole responsibility for the safe and appropriate delivery of medical care to patients. We feel that equipment such as the Vein Display can contribute immensely to the improvement of practical skills, such as safe and proper venipuncture. We would like to emphasize that, for educational processes to be improved, suitable criteria and scales must be developed. Based on the results of this study, we are encouraged to further refine and improve our protocol for the evaluation of safe and appropriate vein selection skill in nursing students.

Disclosure of COI

There was no conflict of interest on this study.

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