Vein Visualization Using Near Infrared (NIR) Vein Finder Technology in Nursing Care: A Review of the Benefits and Shortcomings

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Abstract

Background: Near-Infrared Vein Visualization devices allow for noninvasive identification of veins for multiple uses. This study reviews the benefits and shortcomings of the NIR technique in nursing care based on the literature review.

Materials and Methods A systemic search of electronic databases Medline, SCOPUS, Web of Science, EMBASE, CIVILICA, and Google Scholar search engine was performed with no time limit up to April 2021, using the related keywords alone or in combination.

Results: The use of the NIR to assist intravenous cannulation in pediatric patients significantly reduced the time required for cannulation and the number of cannulation attempts. The results of one study showed the ability and effectiveness of the device in identifying the nature of the vein in real-time for the two studied locations (arm and dorsal hand sites). Another study concluded that wet heat treatment affects the palpation of veins in the experimental and control groups (p<0.01). The results of one study showed that peripheral IV cannulation is easy to use with guidance of ultrasonography and trans-illumination in pediatric patients with difficult venous access, resulting in a high overall success rate of cannulation, particularly for low vein visibility associated with Asian and African-American ethnicity or obesity. A study showed that the first-time insertion success (FTIS) rate was 73%, with a sensitivity of 74.26%, specificity of 57.69%, and a positive predictive value of 82.87%.

Conclusion: The NIR technology is useful in locating the vein for cannulation, providing venous access for blood sampling, therapy, and other medical purposes at a very low cost, for pediatric and elderly patients and others with difficult venous access.

Key Words: Health care, Near-infrared light (NIR), Patients, Nursing.

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1- INTRODUCTION

Based on the literature, about 90% of hospital patients need peripheral intravenous cannulation for administering medications or replacing fluids (1). Also, the literature shows that the highest rate of mistakes in the clinical laboratory involves gathering samples by venipuncture, also known as phlebotomy (2). Identifying the vein is not simple. Some elements affect the visibility of a patient's vasculature, like the difference in the skin of young children (particularly infants), dehydration, and obesity (3). The use of some devices and techniques will help better access the veins, including tourniquets (4), local heating (4–6), ultrasound (7), and trans-illuminating devices (8). A trans-illuminating device is a recent technical innovation that employs near-infrared light-emitting diodes (NIR-LED) to show superficial veins with hemoglobin absorbing the generated light and producing a view on the skin surface (8). NIR-LED is a non-invasive vein detector for the venipuncture processes, such as blood sample collection and drug preparation, which can be utilized for IV administration. The apparatus can be utilized in many patient care sectors where vascular access operations are carried out and may be utilized for all patients, like obese or diabetic people (9). Challenges from various human factors necessitate considering an increased number of parameters and participants/humans for actual vein visualization testing. The literature on the performance of phlebotomy using the vein finding was limited (10). This study aimed to review the benefits and shortcomings of the NIR technique in nursing care based on the literature review.

2- MATERIALS AND METHODS

2-1. Data sources

In this review, a systemic search of electronic databases Medline (via PubMed), SCOPUS, Web of Science, EMBASE, CIVILICA, and Google Scholar search engine was performed with no time limit up to November 2021, using the following keywords alone or in combination: cannulation, phlebotomy, venipuncture, vein finder, vein visualization, vein detector, difficult cannulation, benefits and shortcomings. The search was performed independently and in duplication by two reviewers, and any disagreement was resolved by the supervisor.

2-2. Study selection

Database search was done for suitable studies. Abstracts of the studies were screened to identify eligible studies, full-text articles were obtained and assessed, and a final list of eligible studies was made. This process was done independently and in duplication by two reviewers, and any disagreement was resolved by a third reviewer. References were organized and managed using EndNote software (version X8).

3- RESULTS

3-1. Near-Infrared Vein Finder

Near-Infrared Vein Visualization devices allow for noninvasive identification of veins for multiple uses. They function by illuminating the skin with near-infrared light (700e900 nm), which penetrates the skin and subcutaneous tissues to a depth of approximately 3 mm (Lingyu and Leedham, presented at the IEEE International Conference on Video and Signal Based Surveillance, 2006) (**Figure.1**). The light is differentially absorbed by the underlying tissues, with increased absorption by deoxygenated hemoglobin. The difference in absorption is detected by the device camera, and the reproduction is projected onto the subject's skin in real-time. The technique is commonly used in pediatric hospitals for

improving intravenous access and aid in venous access in difficult situations (11). It has also been used to identify potential donors for vein grafts as it minimizes the incision size at the harvest site and assists the planning and design of free flaps for breast reconstruction (27, 28). The device is designed to help identify blood vessels. The light emitted from the device provides a clearer view for the nurse performing the intravenous cannulation process (12).

A medical near-infrared vein visualization device (VVD) is used for detecting the peripheral superficial vessels (13). This technology also facilitates vein access for nurses who have difficulty performing an intravenous cannula due to patient characteristics related to skin color, vein condition, and vein diameter (14). The effective role of this technique has been clarified, especially for the contribution to cases with difficult intravenous cannulation to reduce the number of cannulation attempts and facilitate successful cannulation (15). Tools like the Vein Display can immensely advance the professional skills of second-year nursing students, such as venipuncture, specifically in aging patients (16).
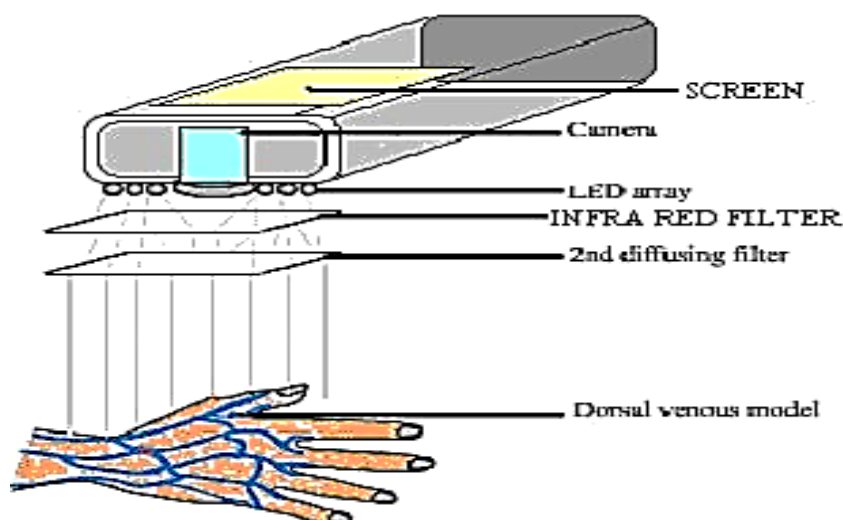
Fig 1: Working principle of the model (17).

3-2. Device Characteristics

▪ The device shows a map of the vascular network on the skin in real-time, allowing medical caregivers to ascertain the vein's path and avoid tortuosity.

▪ Its light weight allows it to be carried by hand and it can be easily converted into a free position (without hands) through wheeled or fixed stands.

▪ The device can be easily wiped and cleaned due to its special design (**Figure.2**).

▪ The device is easy to use on the intended vein.

▪ It can be used on patients with different characteristics.

▪ It makes venipuncture very effective and reduces the patient's discomfort.

▪ The apparatus is suitable for patient movement because it offers the vessels in true time if switched on accurately (18).

Fig. 2: Portable Vein Viewer Locator Detector Trans-illuminator Visualization Lights for Clinic (19).

3-3. Literature Review

Finally, seven related articles were selected.

1. A review study by Pan et al. (2007-2018) titled "Vein Pattern Locating Technology for Cannulation: A Review of the Low-Cost Vein Finder Prototypes Utilizing near Infrared (NIR) Light to Improve Peripheral Subcutaneous Vein Selection for Phlebotomy" discussed the limitations of the published studies dealing with evaluating people who perform venipuncture, the differences in their research methodology, the number and type of patients based on demographics,

and the tools used in evaluating the developed prototypes. The study also showed the limitations of research on the actual testing of the initial model on humans. The study indicated that the development of an effective, affordable NIR vein residual is in the optimization stage (20).

2. A randomized prospective study by Chiao et al. (2012) titled "Vein visualization: patient characteristic factors and efficacy of a new infrared vein finder technology" examined the characteristics of patients that are associated with the detection of venipuncture areas without any visual assistance. In this study, patient

characteristics, including age, gender, height (inches), weight (pounds), ethnicity, and skin color, were collected from every study sample. Observers, including skilled phlebotomists, physicians, and nurses in venipuncture, investigated at least ten independent characteristics each. Each characteristic was examined via both the conventional method and the infrared vein finding (VF) device. The results demonstrated a power analysis for moderate effect size $(\beta=0.95)$ requiring 54 samples for within-subject differences. As a whole, the conventional method (CM) of vein visualization was less effective in 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. Consequently, vein visibility was decreased in these patients. The new infrared device improves the visibility of veins for cannulation in all participants (21).

3. A prospective, quasi-experimental study was conducted by Saju et al. (2019) titled "Use of a vein-viewing device to assist intravenous cannulation decreases the time and number of attempts for successful cannulation in pediatric patients". The study was performed in a children's hospital to examine the effect of the vein detector (VTorch) on the process of cannulation. In the experimental group, a LED-based vein-viewing device (VTorch) was used to assist intravenous cannulation. In the control group, intravenous cannulations were done under normal lighting as the routine hospital procedure. The number of cannulation attempts and the time required for successful cannulation were assessed. The effect of the device on pain, fear, and behavioral distress associated with children was also evaluated. The use of the device as an intravenous cannulation aid significantly reduced the time taken for cannulation, cannulation (p=0.003), and the number of cannulation attempts (P=0.03). Moreover,

the success rate of the first cannulation attempt increased with this device (P=0.04). Pain, fear, or behavioral distress associated with the cannulation among the research participants were unaffected by device use. The results of this study may help improve the quality of venous puncture in children (22).

4. Francisco et al. (2021) conducted a randomized control trial titled "Competitive Real-Time Near Infrared (NIR) Vein Finder Imaging Device to Improve Peripheral Subcutaneous Vein Selection in Venipuncture for Clinical Laboratory Testing". They used near-infrared technology to develop a low-cost real-time near-infrared (NIR) router for cannulation. The study included several healthcare providers and students to train and develop their abilities in performing cannulation. They first developed a reflective-type optical vein finder using three (23) light-emitting diode (LED) lights with a wavelength of 960 nm and a complimentary infrared (CMOS-IR) sensor camera with 1920× 1080 UXGA (1080P) infrared filter set for the specified wavelength, and open-source image processing software. Next, they carried out the actual testing in a human lab at two locations, the arm and the back of the hand on 242 people. The included indicators were gender, age, body mass index (BMI), and skin color. To evaluate the device, the researchers included the circumference of the arm. The difference in vein images was compared by digital and visual imaging. The results of the study showed the effectiveness of the device in identifying the vein in real-time for both locations (arm and dorsal hand sites) (24).

5. Samra et al. (2018) conducted a study titled "Effectiveness of Moist Heat Therapy on Visibility, Palpability, Pricks, and Pain Experienced While Undergoing Peripheral Intravenous Cannulation of Patients". A quasi-experimental method was used to evaluate the effect of moist

heat therapy on vision, palpation, tingling, and pain during peripheral venipuncture. The sample size was 100 (50 in the control group, 50 in the experimental group) gathered in the purposeful method from patients admitted in oncology wards of DMC & Hospital, Ludhiana, India. The study indicated the significant effect of moist heat treatment on palpation of veins in the experimental and control groups ($p<0.01$). It also showed that the number of intravenous cannulation attempts and the cannulation pain in both groups reached a significance level of $p<0.01$. This indicates the positive effect of moist heat therapy on supporting the vision and palpation of the vein and relieving and reducing the number of cannulation attempts and pain during venous cannulation (25).

6. Girgis et al. (2013) conducted a study titled "Ultrasound guidance versus transillumination for peripheral intravenous cannulation in pediatric patients with difficult venous access" at the Cairo University Children's Hospital to compare the effect of ultrasonography to trans-illumination (under inhaled anesthesia) on peripheral intravenous cannulation in pediatric patients. A total of 80 samples (40 for ultrasound and 40 for veinlite), similar in their demographic and clinical characteristics, were included in the study. The time required for cannulation and the number of attempts was measured. The study showed that peripheral IV cannulation is easy with ultrasonography and trans-illumination in pediatric patients with difficult venous access, resulting in a high overall success rate of cannulation. The results of the sonar device were better than trans-illumination (26).

7. Carr et al. conducted a prospective cohort study titled "Factors associated with peripheral intravenous cannulation first-time insertion success in the emergency department: A multicenter prospective cohort analysis of patient, clinician and product characteristics". The study sample included 879 patients, and 1,201 cannulas were inserted into the peripheral vein by physicians specializing in emergency medicine. The final form combined the characteristics of the patient, clinical, technological, and product characteristics that had a higher discriminatory effect than the specific forms of characteristics. Its sensitivity was 74.26%, its specificity was 57.69%, its positive predictive value was 82.87%, and its predictive value was negative 44.85%. Thus, first-time insertion success (FTIS) can be improved by more experienced and self-reliant physicians (27).

4- CONCLUSION

The NIR technology is recommended as a useful guiding device in nursing care, medical practitioners, and students for their training and helps in locating the vein for cannulation, providing venous access for blood sampling, therapy, and other medical purposes for pediatric, elderly, and other patients with difficult venous access. The positive effect of moist heat therapy is also indicated on supporting the vision and palpation of the vein and reducing the number of cannulation attempts and pain during venous cannulation. FTIS can be improved by more experienced and self-reliant nurses and physicians.

5- AUTHORS' CONTRIBUTIONS

Study conception or design: SFA, HK, and SA; Data analyzing and draft manuscript preparation: SFA, and MB; Critical revision of the paper: HK, and MB; Supervision of the research: HK and SA; Final approval of the version to be published: SFA, HK, SA, and MB.

6- CONFLICT OF INTEREST: None.

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