Technical Report

Effectiveness of using near-infrared vein visualizers by nurses in promoting successful peripheral venous catheterization in patients receiving chemotherapy

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Abstract

Objective: Visibility and palpability of peripheral veins may affect peripheral intravenous catheterization (PIVC) failure and complications. A near-infrared (NIR) vein visualizer is recommended to select peripheral veins with low visibility. Chemotherapy reduces the number of peripheral veins suitable for PIVC; however, no study has shown that NIR vein visualizers can prevent PIVC failures during chemotherapy. We investigated the effectiveness of using an NIR vein visualizer by nurses for PIVC during chemotherapy. **Technical Report:** We investigated the vein characteristics (i.e., visibility, palpability), PIVC difficulty before puncture, and success or failure. The study field was a chemotherapy room at the General Hospital (Shizuoka, Japan). The study participants were nurses who performed PIVC in patients receiving chemotherapy. Six nurses were enrolled, and eighty-four PIVC cases were obtained (with duplicate patients). There were 34 cases in the NIR vein visualizer group and 50 in the standard insertion group; the NIR vein visualizer group had a significantly higher number of difficult PIVC cases ($p < .01$). Peripheral veins with successful PIVC in the NIR vein visualizer group had significantly higher visibility and palpability than those with PIVC failure ($p < .05$). **Conclusions:** During chemotherapy, nurses used an NIR vein visualizer for the peripheral veins deemed difficult to catheterize; PIVC was successfully performed in the peripheral veins with high palpability. The results showed that an NIR vein visualizer facilitates successful PIVC during chemotherapy.

Keywords

peripheral intravenous catheterization, vein visualizer, chemotherapy, infusion therapy, near-infrared

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Introduction

To safely perform peripheral intravenous catheterization (PIVC), determining the appropriate site, thickness, and length of the peripheral vein by visually examining the contours of the peripheral vein and palpating it with the fingertips is necessary (Gorski et al., 2021). However, puncture failure or complications occur in 20%-70% of PIVC cases (Jacobson & Winslow, 2005; Murayama et al., 2017; Wallis et al., 2014). Visibility and palpability of peripheral veins

may affect PIVC failure and complications (Jacobson & Winslow, 2005; Piredda et al., 2017). The visibility of peripheral veins decreases with the distance from the skin surface, starting at a distance of 3 mm (Kimori et al., 2011). Palpability decreases with the distance from the surface of the skin and a smaller cross-sectional area (Ichimura et al., 2015). Additionally, the contact of the PIVC needle with the vein's inner wall may cause edema in the peripheral veins (Murayama et al., 2015; Takahashi et al., 2017), resulting in the extravasation of the chemotherapy medications. Deter-

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mining visible and palpable peripheral veins may lead to safer and successful PIVC.

A vein visualizer is recommended to select peripheral veins with low visibility (Gorski et al., 2021). Near-infrared (NIR) vein visualizers are based on the absorption of NIR light by hemoglobin in the peripheral veins. AccuVein[®], an NIR vein visualizer, can visualize superficial peripheral veins by projecting lasers of two different wavelengths, visible and infrared, onto the skin to depict peripheral veins as black lines on the skin. However, no previous study has shown that NIR vein visualizers can prevent PIVC failures. In a study of pediatric to elderly patients with hemophilia requiring multiple PIVC, there was no association found between PIVC success and failure with the use of an NIR vein visualizer (Guillon et al., 2015). A similar previous study, wherein a randomized controlled trial of patients in their 50's-60's was conducted in the emergency room also found no association between success and failure of PIVC with the use of an NIR vein visualizer (Aulagnier et al., 2014). Because the NIR vein visualizer assists with peripheral vein visibility, it may not be effective for highly visible peripheral veins. Since the visibility and palpability of peripheral veins and the difficulty of PIVC in patients were not uniform in previous studies, it is necessary to limit the study to peripheral veins with a high difficulty of PIVC.

Chemotherapy reduces the number of peripheral veins suitable for PIVC due to multiple PIVC within the treatment period. Regardless of chemotherapy, patients undergoing PIVC complain of pain, anxiety, despair, and fear of repeated punctures, making failed punctures unbearable (Plohal, 2021). Furthermore, anticancer drugs can cause ulceration and necrosis if even a small amount leaks outside the vessel; therefore, a peripheral vein must be carefully selected, which makes PIVC more difficult for nurses. No report has investigated the efficacy of NIR vein visualizers for PIVC in patients receiving chemotherapy. We used NIR vein visualizers because PIVC for chemotherapy is difficult due to low visibility and palpability. Visibility assisted by an NIR vein visualizer may promote the success of PIVC. We investigated whether NIR vein visualizers promote the success of PIVC in patients receiving chemotherapy.

Technical Report

Objective

We investigated whether the use of an NIR vein visualizer by nurses promotes successful PIVC in patients receiving chemotherapy.

Methods

Study Design

This study used a quantitative, descriptive research design. The study field was a chemotherapy room in a general hos-

pital in Japan. The study period was from December 2019 to March 2020. The participants were nurses who had performed PIVC in patients receiving chemotherapy. The nurses used an NIR vein visualizer for PIVC during their routine work. A questionnaire was created by the researchers, and the nurses were asked to complete the questionnaire.

Study Participants

Nurses were not restricted by their years of experience. The patients were adults, and there were no restrictions on age, sex, or disease.

Recruitment of Research Participants

The researchers made a documented and oral research request to the head nurse of a general hospital in Japan and obtained her consent. The researchers explained the research to the nurses in writing and orally and obtained their consent. For the patients, the researchers provided the nurses with oral and written explanations and obtained the patients' consent.

Data Collection

Survey Questionnaire

The nurses' data regarding gender, years of experience, final education course, and frequency of PIVC were collected. The nurses filled out questionnaires for difficult-to-perform PIVC cases. The items on the questionnaire were the patient's gender, age, body size, peripheral vein characteristics (i.e., thickness, elasticity, tortuous veins, rolling veins, visibility, and palpability), PIVC difficulty before puncture, and success or failure. Peripheral vein characteristics and PIVC difficulty were rated using a 10-point scale, ranging from 1 to 10, to define peripheral vein catheterizations that ranged from easy to difficult, respectively.

Investigational Devices

The NIR vein visualizer AccuVein[®] AV400 was used in this study and purchased from a Grant-in-Aid for Scientific Research (Grant-in-Aid for Early-Career Scientists B: 17K 17409).

Statistical Analysis

A database was created based on a survey questionnaire. Based on the database, the cases were divided into two groups as follows: a standard insertion group without an NIR vein visualizer and an NIR vein visualizer group using the AccuVein[®] AV400. Furthermore, the PIVC was divided into success and failure groups. The difference between the groups in the contingency table was determined using the chi-squared test, and the 10-point scale was determined using the Mann-Whitney U test. Multiple logistic regression analysis was used for the ordinal scale to explore the association between each of the success of PIVC and vein characteristics. Data were analyzed using the IBM SPSS Statistics version 27 (IBM Corp., Armonk, NY, USA).

Ethical Considerations

This study was conducted after obtaining approval from the University of Shizuoka Research Ethics Review Committee

Table 1. Description of PIVC.

NIR vein visualizer group <i>n</i> = 34		Standard insertion group <i>n</i> = 50	
Success <i>n</i> (%)	Failure <i>n</i> (%)	Success <i>n</i> (%)	Failure <i>n</i> (%)
20 (58.8%)	14 (41.2%)	38 (76.0%)	12 (24.4%)

Note. $p = .095$ (chi-squared test).

Abbreviations: NIR, near-infrared; PIVC, peripheral intravenous catheterization.

(Approval No. 30-37). The researchers explained to the nurses that they could freely decide not to participate in the study, to withdraw their consent at any time, the invasiveness of the measurements and how to handle them, the protection of personal information, and the publication of the study results. For patients, the nurses explained the research and obtained their consent.

Results

Demographics of the Nurses

The study participants were six nurses, with an average of 28.3 ± 7.1 years of nursing experience, four in the 3-year final education program and two in the certified nursing program. All nurses performed at least one PIVC per day.

Description of the PIVC

In total, 84 PIVC cases (duplicate patients) were included. The gender was male in 40 cases (47.6%) and female in 44 cases (52.4%). The mean age was 67.1 ± 10.2 years, with a minimum of 42 years and a maximum of 87 years. The body types were thin, 14 (16.7%); normal, 55 (65.5%); and obese, 15 (17.9%). The NIR vein visualizer group included 34 cases, of which 20 (58.8%) were successful and 14 (41.2%) failed. The standard insertion group included 50 cases, of which 38 (76.0%) were successful and 12 (24.4%) failed. There was no significant difference in the success and failure of PIVC between the NIR vein visualizer and the standard insertion groups ($p = .095$, Table 1).

Comparison of the PIVC Difficulty

With respect to PIVC difficulty, the NIR vein visualizer group had a significantly higher number of difficult PIVC cases than the standard insertion group ($p < .05$, Table 2).

Relationship between PIVC Success and Vein Characteristics
Peripheral veins with successful PIVC in the NIR vein visualizer group had significantly higher visibility and palpability than those with PIVC failure ($p < .05$, Table 3). We performed a logistic regression analysis in the NIR vein visualizer group using peripheral vein visibility and palpability as independent variables and PIVC success as the dependent variable. The results showed a significant association between palpability and PIVC success ($p = .04$), with an odds ratio of 1.67 (95% IC 1.03-2.69). In the standard insertion group, no significant association was observed between pe-

Table 2. Comparison of the PIVC difficulty.

	NIR vein visualizer group <i>n</i> = 34			Standard insertion group <i>n</i> = 50			<i>p</i> value
	Mean	SD	Median	Mean	SD	Median	
Difficulties with PIVC	9.06	1.63	10.00	7.06	2.58	8.00	<.01
				**			

Note. Results tested by Mann-Whitney U test.

** $p < .01$; a score of 10 is more difficult than a score of 1.

Abbreviations: PIVC, peripheral intravenous catheterization; SD, standard deviation.

Table 3. Vein characteristics in the NIR vein visualizer group.

Vein characteristic	NIR vein visualizer group						<i>p</i> value
	Success (<i>n</i> = 20)			Failure (<i>n</i> = 14)			
	Mean	SD	Median	Mean	SD	Median	
Thickness	7.65	3.15	9.00	9.43	1.02	10.00	.05
Elasticity	7.45	2.56	8.00	9.07	1.21	10.00	.06
Tortuous veins	8.05	2.26	9.00	9.21	1.31	10.00	.07
Rolling veins	7.35	2.64	8.00	8.29	2.05	8.50	.30
				*			
Visibility	7.45	3.02	9.00	9.14	1.99	10.00	.02
				*			
Palpability	6.95	3.07	7.00	9.21	1.31	10.00	.01

Note. Results showed by Mann-Whitney U tests.

* $p < .05$; a score of 10 is more difficult than a score of 1.

Abbreviations: NIR, near-infrared; SD, standard deviation.

Table 4. Vein characteristics in the standard insertion group.

Vein characteristic	Standard insertion group						<i>p</i> value
	Success (<i>n</i> = 38)			Failure (<i>n</i> = 12)			
	Mean	SD	Median	Mean	SD	Median	
Thickness	5.58	2.89	5.00	6.58	2.71	6.50	.26
Elasticity	6.11	2.63	5.00	5.75	3.02	5.00	.65
Tortuous veins	6.21	3.01	7.00	6.50	2.61	6.00	.77
Rolling veins	7.11	2.49	7.50	5.08	3.65	5.00	.09
Visibility	5.63	3.31	5.00	5.08	3.23	3.00	.58
Palpable vein	4.84	3.12	4.50	5.00	3.13	3.00	.95

Note. Results showed by Mann-Whitney U tests. A score of 10 was more difficult than a score of 1.

ripheral vein characteristics and PIVC success or failure (Table 4).

Discussion

This study investigated if the use of an NIR vein visualizer by nurses can promote successful PIVC in patients receiving

chemotherapy. We compared the outcome of using an NIR vein visualizer with that of using standard insertion. The results showed that nurses used NIR vein visualizer on peripheral veins with high PIVC difficulty; hence, PIVC was successful in peripheral veins with high palpability.

This study examined patients receiving chemotherapy, assuming a high degree of difficulty in PIVC; however, similar to previous studies (Aulagnier et al., 2014; Guillon et al., 2015), the NIR vein visualizer was not associated with PIVC success or failure (Table 1). We speculated that since the NIR vein visualizer group had a higher PIVC difficulty than the standard insertion group (Table 2), there was no difference between PIVC success and failure. There was no significant difference in the characteristics of the peripheral veins between PIVC success and failure cases in the standard insertion group; however, peripheral vein visibility and palpability in the NIR vein visualizer group significantly differed between the PIVC success and failure cases (Table 3, 4). Furthermore, in the logistic regression analysis, palpability was associated with PIVC success. The results showed that PIVC was successful in peripheral veins with high palpability when the NIR vein visualizer was employed. Using NIR vein visualizers in patients with difficult PIVC facilitated the identification of peripheral veins. Peripheral vein palpability was associated with PIVC success. Therefore, PIVC success can be enhanced if nurses select a palpable peripheral vein using the NIR vein visualizer. The NIR vein visualizer can assist in detecting peripheral veins (Guillon et al., 2015); however, it cannot assess their depth (Kaddoum et al., 2012) and thickness. The depth and thickness of the peripheral veins can be assessed via palpation. Since these parameters are important for PIVC, previous studies have investigated the promotion of peripheral vein size (Ichimura et al., 2015; Yamagami et al., 2017). Therefore, although it is difficult to visualize the veins, the success rate of PIVC can be increased if nurses promote peripheral vein size and select palpable peripheral veins using an NIR vein visualizer. In chemotherapy, if the palpability of peripheral veins can be assessed using an NIR vein visualizer, PIVC may be successful.

This study showed that the palpability of peripheral veins is important. The palpation technique used to determine suitable peripheral veins for PIVC is challenging to explain; however, no standardized method for teaching palpation techniques has yet been established. In the future, investigating the palpation technique will be required for peripheral veins that skilled nurses cannot visualize. Our study showed that using an NIR vein visualizer in chemotherapy patients increased the ability of nurses to select more palpable peripheral veins, which promoted the success of PIVC. Specifically, in the NIR vein visualizer group, the success rate of PIVC was higher when the peripheral veins were more palpable. The use of vein visualizer devices is recommended

for difficult PIVC; therefore, this study provides a new indication of the extent to which the NIR vein visualizers can be effectively operated. This result is clinically significant because it can impact the success rate of PIVC.

Conclusion

During chemotherapy, nurses used an NIR vein visualizer for peripheral veins evaluated as difficult to catheterize, and PIVC was successfully performed in peripheral veins with high palpability. The results showed that the use of an NIR vein visualizer by nurses facilitates successful PIVC in patients receiving chemotherapy.

Limitations

The nurses subjectively surveyed the depth and thickness of the peripheral veins; therefore, objective measurements are needed. Furthermore, for a successful PIVC, the application of NIR vein visualizers and properties of peripheral veins need to be investigated.

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Author Contributions

NK designed the study, coordinated the research sites, collected the data, and analyzed and interpreted the data. YW supervised the study design and data analysis and was a major contributor in writing the manuscript.

Conceptualization: NK; methodology: NK, YW; formal analysis and investigation: NK, YW; writing-original draft preparation: NK; writing-review and editing: NK; funding acquisition: NK; resources: NK; supervision: NK, YW. All authors read and approved the final manuscript.

Declaration of Conflicting Interests

There are no conflicts of interest to declare.

Ethical Approval

This study was conducted after obtaining approval from the University of Shizuoka Research Ethics Review Committee (Approval No. 30-37).

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References

- Aulagnier, J., Hoc, C., Mathieu, E., Dreyfus, J. F., Fischler, M., & Le Guen, M. (2014). Efficacy of AccuVein to facilitate peripheral intravenous placement in adults presenting to an emergency department: A randomized clinical trial. *Academic Emergency Medicine*,

- 21(8), 858-863. <https://doi.org/10.1111/acem.12437>
- Gorski, L., Hadaway, L., Hagle, M., Broadhurst, D., Clare, S., Kleidon, T., Meyer, B., Nickel, B., Rowley, S., Sharpe, E., & Alexander, M. (2021). Infusion therapy standards of practice, 8th edition. *Journal of Infusion Nursing*, 44(1S), S1-S224. <https://doi.org/10.1097/NAN.0000000000000396>
- Guillon, P., Makhoulfi, M., Baillie, S., Roucoulet, C., Dolimier, E., & Masquelier, A. M. (2015). Prospective evaluation of venous access difficulty and a near-infrared vein visualizer at four French haemophilia treatment centres. *Haemophilia*, 21(1), 21-26. <https://doi.org/10.1111/hae.12513>
- Ichimura, M., Sasaki, S., Mori, M., & Ogino, T. (2015). Tapping but not massage enhances vasodilation and improves venous palpation of cutaneous veins. *Acta Medica Okayama*, 69(2), 79-85. <https://doi.org/10.18926/AMO/53336>
- Jacobson, A. F., & Winslow, E. H. (2005). Variables influencing intravenous catheter insertion difficulty and failure: An analysis of 339 intravenous catheter insertions. *Heart & Lung*, 34(5), 345-359. <https://doi.org/10.1016/j.hrtlng.2005.04.002>
- Kaddoum, R. N., Anghelescu, D. L., Parish, M. E., Wright, B. B., Trujillo, L., Wu, J., Wu, Y., & Burgoyne, L. L. (2012). A randomized controlled trial comparing the AccuVein AV300 device to standard insertion technique for intravenous cannulation of anesthetized children. *Paediatric Anaesthesia*, 22(9), 884-889. <https://doi.org/10.1111/j.1460-9592.2012.03896.x>
- Kimori, K., Sugama, J., Nakatani, T., Fukuda, S., Miyati, T., Konya, C., Okuwa, M., Sanada, H. (2011). Masyojoumyakukateeteru nioite Mokushikonnanna Joumyaku wo Kakujitu Anzenni Senshisurutameno Kisokenkyu [Investigation of invisible peripheral veins for certain and safe venipuncture in catheter placement: Non-invasive measurement of width, depth, and skin color]. *Japanese Journal of Nursing Art and Science*, 10(1), 103-110. https://doi.org/10.18892/jsnas.10.1_103
- Murayama, R., Takahashi, T., Tanabe, H., Yabunaka, K., Oe, M., Oya, M., Uchida, M., Komiyama, C., & Sanada, H. (2015). The relationship between the tip position of an indwelling venous catheter and the subcutaneous edema. *BioScience Trends*, 9(6), 414-419. <https://doi.org/10.5582/bst.2015.01114>
- Murayama, R., Uchida, M., Oe, M., Takahashi, T., Oya, M., Komiyama, C., & Sanada, H. (2017). Removal of peripheral intravenous catheters due to catheter failures among adult patients. *Journal of Infusion Nursing*, 40(4), 224-231. <https://doi.org/10.1097/NAN.0000000000000168>
- Piredda, M., Biagioli, V., Barrella, B., Carpisassi, I., Ghinelli, R., Giannarelli, D., & De Marinis, M. G. (2017). Factors affecting difficult peripheral intravenous cannulation in adults: a prospective observational study. *Journal of Clinical Nursing*, 26(7-8), 1074-1084. <https://doi.org/10.1111/jocn.13444>
- Plohal, A. (2021). A qualitative study of adult hospitalized patients with difficult venous access experiencing short peripheral catheter insertion in a hospital setting. *Journal of Infusion Nursing*, 44(1), 26-33. <https://doi.org/10.1097/nan.0000000000000408>
- Takahashi, T., Murayama, R., Oe, M., Nakagami, G., Tanabe, H., Yabunaka, K., Arai, R., Komiyama, C., Uchida, M., & Sanada, H. (2017). Is thrombus with subcutaneous edema detected by ultrasonography related to short peripheral catheter failure? A prospective observational study. *Journal of Infusion Nursing*, 40(5), 313-322. <https://doi.org/10.1097/NAN.0000000000000216>
- Wallis, M. C., McGrail, M., Webster, J., Marsh, N., Gowardman, J., Playford, E. G., & Rickard, C. M. (2014). Risk factors for peripheral intravenous catheter failure: A multivariate analysis of data from a randomized controlled trial. *Infection Control & Hospital Epidemiology*, 35(1), 63-68. <https://doi.org/10.1086/674398>
- Yamagami, Y., Tomita, K., Tsujimoto, T., & Inoue, T. (2017). Tourniquet application after local forearm warming to improve venodilation for peripheral intravenous cannulation in young and middle-aged adults: A single-blind prospective randomized controlled trial. *International Journal of Nursing Studies*, 72, 1-7. <https://doi.org/10.1016/j.ijnurstu.2017.03.009>