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INFRARED VEIN IMAGING FOR INSERTION OF PERIPHERAL INTRAVENOUS CATHETER FOR PATIENTS REQUIRING ISOLATION FOR SEVERE ACUTE RESPIRATORY SYNDROME CORONAVIRUS 2 INFECTION: A NONRANDOMIZED CLINICAL TRIAL

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Contribution to Emergency Nursing Practice

- Evidence on peripheral intravenous access assistive technology has mainly applied to venipuncture in children.
- Infrared vein imaging may help nurses improve the peripheral intravenous access first attempt success rate, efficiency, and patient satisfaction among adult patients under pandemic infectious respiratory disease isolation conditions.
- The results of this nonrandomized study support the use of infrared vein imaging among adult emergency patients who require infectious disease isolation that may create difficulty in performing peripheral intravenous access procedures.

Abstract

Introduction: Establishing intravenous access is essential but may be difficult to achieve for patients requiring isolation for severe acute respiratory syndrome coronavirus 2 infection. This study aimed to investigate the effectiveness of an infrared vein visualizer on peripheral intravenous catheter therapy in patients with coronavirus disease 2019.

Methods: A nonrandomized clinical trial was performed. In total, 122 patients with coronavirus disease 2019 who required peripheral intravenous cannulation were divided into 2 groups with 60 in the control group and 62 in the intervention group. A conventional venipuncture method was applied to the control group, whereas an infrared vein imaging device was applied in the intervention group. The first attempt success rate, total

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procedure time, and patients' satisfaction score were compared between the 2 groups using chi-square, *t* test, and *z* test (also known as Mann-Whitney U test) statistics.

Results: The first attempt success rate in the intervention group was significantly higher than that of control group (91.94% vs 76.67%, $\chi^2 = 5.41$, $P = .02$). The procedure time was shorter in the intervention group (mean [SD], 211.44 [68.58] seconds vs 388.27 [88.97] seconds, $t = 12.27$, $P < .001$). Patients from the intervention group

experienced a higher degree of satisfaction (7.5 vs 6, $z = -3.31$, $P < .001$).

Discussion: Peripheral intravenous catheter insertion assisted by an infrared vein visualizer could improve the first attempt success rate of venipuncture, shorten the procedure time, and increase patients' satisfaction.

Key words: COVID-19; Infrared vein visualizer; Peripheral intravenous catheter insertion

Introduction

Coronavirus disease 2019 (COVID-19) is highly contagious and transmissible, requiring isolation precautions during treatment. Respiratory droplets and close contact were recognized as the major virus transmission routes in the early phases of the pandemic, and the population is generally susceptible.¹ Therefore, patients must be treated in isolation conditions, and health care staff needs to wear personal protective equipment. In many international settings, the required personalized protective equipment included goggles.² This personalized protective equipment presents challenges and additional workload when providing nursing care. The evaporated body heat forms water vapor in goggle glasses, which may block nurses' eyesight. Moreover, wearing an extra layer of gloves negatively affects the palpating sensation. Nursing responsibilities commonly include peripheral intravenous cannulation (PIVC). Traditionally, nurses rely on their senses of sight and touch to perform PIVC. However, under isolation ward conditions described in earlier text, nurse proceduralists may not be able to see the vein clearly and assess the venous elasticity well, making venipuncture particularly difficult.

The infrared vein imaging device emits infrared wavelength of 4 to 400 μm with a 3 to 5 cm penetration depth to pass through the skin and subcutaneous fat efficiently. On absorbing the infrared wave, the vein turns blue-green. Hence, the distribution and direction of subcutaneous veins, especially those invisible to the naked eye, can be clearly displayed by an infrared vein imaging instrument.³ In brief, infrared imaging could facilitate the identification of the most suitable blood vessels for PIVC. Accordingly, the first attempt success rate may be increased, and the total procedure time may be shortened using the infrared imaging device to locate suitable PIVC sites. Evidence from a review of the literature indicates that infrared vein imaging technology is effective in improving PIVC outcomes,

especially for patients with less visible veins.^{4,5} Sun et al⁶ reported that the near-infrared (NIR) vein-viewing device could help decrease the time for finding the first available blood vessel (mean = 383.61, SD = 112.14 vs mean = 126.37, SD = 26.33 seconds) and decrease the number of PIVC attempts (2 vs 1 median of attempts per patient) in critically ill children.⁶ In a systematic review, Park et al⁷ concluded that the use of an NIR device did not influence the overall failure rate at the first attempt of PIVC in pediatric patients. However, in a subset of patients at high risk, which were determined by the clinician's subjective rating of difficulty or an objective index for difficulty (difficult intravenous access score or skin color grading), using NIR light devices showed a lower risk for PIVC failure than the traditional method. Patients with poor vascular conditions in isolation wards may be considered high risk for PIVC failure. Previously, we have applied infrared vein imaging assisted venipuncture in patients with rheumatic diseases with increased efficiency (procedure time shortened from an average of 382.11 seconds to 203.06 seconds).⁸ To our knowledge, no similar study on NIR light devices and PIVC outcomes has been conducted with patients in COVID-19 isolation settings. To address the gaps in the literature, combined with our own experience under the COVID-19 disaster conditions, this present study aimed to evaluate the effectiveness of the infrared vein visualizer on PIVC outcomes for patients in COVID-19 isolation.

HYPOTHESIS

Our hypothesis was that the intervention group with the infrared vein visualizer for PIVC would demonstrate (1) increased success rate at the first attempt, (2) shorter procedure time, and (3) increased satisfaction compared with the control group.

Methods

STUDY DESIGN

This was a nonrandomized, double-blinded by not knowing the conditions under study, and controlled clinical trial performed in patients of the COVID-19 isolation wards from February 2020 to April 2020. The study was conducted in Tongji hospital (Wuhan, China), where each unit contained 50 beds and 30 working staff during the COVID-19 outbreak.

PARTICIPANT ALLOCATION

A randomization method was not adopted because it was difficult to conduct grouping in the isolation environment and justify under the rapidly changing disaster conditions. The control group and the intervention group were from 2 different COVID-19 isolation wards, respectively. The control group adopted the traditional venipuncture approach. The intervention group adopted the infrared vein visualizer–assisted approach. The study followed TREND guideline guidance.⁵

PARTICIPANT INCLUSION AND EXCLUSION CRITERIA

Patients (all adults aged ≥ 18 years) were enrolled from 2 isolation wards of the same hospital where patients who were severe and critically ill with COVID-19 were treated. Inclusion criteria for patients included the following: (1) patients positive for severe acute respiratory syndrome coronavirus 2 nucleic acid test with ground-glass shadow on computed tomography image of bilateral lungs; (2) patients needing PIVC; and (3) patients with veins classified as level 0 to 2 according to the standard proposed by Li et al¹⁰ as follows:

- Level 0: Subcutaneous superficial thick veins at the back of the hand and foot or thick veins at the forearm and wrist. Veins prominently protrude on the skin surface with good tension, fixed shape, and an elastic, soft touch.
- Level 1: Subcutaneous superficial small- and medium-sized veins at the back of the hand and foot or medium-sized veins at the forearm and wrist. Veins slightly protrude on the skin surface, and they are touchable but not stiff.
- Level 2: Obscure small veins at the back of the hand and foot or small veins in the fingers. Veins are non-fully filled, less palpable, and partially stiff.

- Level 3: Obscure small veins at other sites. Subcutaneous veins are stiff, hardly palpable, and/or accompanied with phlebitis.

Exclusion criteria were as follows: (1) patients with unstable vital signs, unconsciousness, or restlessness related to conditions such as shock, respiratory failure, and multiorgan dysfunction; and (2) veins at level 3.

PROCEDURALISTS

Nurse proceduralists were required to have at least 3 years working experience with solid competency and success rate of venipuncture outside the COVID units. All nurses on the intervention unit received training on how to operate the infrared instrument (Type AV300, Accu Vein Company, USA).

OUTCOME MEASURES

The effectiveness of an infrared vein visualizer on PIVC was evaluated by the success rate at the first-time attempt, procedure time, and patients' satisfaction degree. A successful PIVC satisfied the following criteria: (1) after the intravenous indwelling needle puncture, there was blood return; (2) once the needle was immobilized and the infusion speed was accurately adjusted, 100 mL of intravenous fluid was successfully injected without evidence of extravasation.

Procedure time referred to the time spent from placing a tourniquet on the upper arm to the accomplishment of venipuncture and was recorded by the data collector. Patients' satisfaction degree on the PIVC procedure was determined by a 0 to 10 visual analog scale scoring with 0 denoting the most unsatisfactory and 10 denoting the most satisfactory.

SAMPLE SIZE

Referring to previous studies^{5,6} in which approximately 30 patients were included in each group with the same intervention and outcome measurement adopted, this study expanded the sample size to 60 patients in each group.

DATA COLLECTION PROCEDURES

During the daily operation, a specified data collector who was a nurse qualified in PIVC was assigned to record the success rate of the first attempt, the time taken for the venipuncture, and the satisfaction score immediately after the

TABLE 1
The baseline characteristics of patients

Characteristics	Control n = 60		Intervention n = 62		Statistics		P value
	Mean or n	SD or %	Mean or n	SD or %	Test	Value	
Age, y, mean (SD)	55.75	10.68	55.79	11.10	<i>t</i>	-0.02	.98
Sex, n (%)							
Female	21	35.00	24	38.71	χ^2	0.18	.67
Male	39	65.00	38	61.29			
Blood pressure, mm Hg, mean (SD)							
Systolic	118.01	8.89	120.90	11.67	<i>t</i>	-1.55	.12
Diastolic	72.27	8.24	73.82	8.34	<i>t</i>	-1.04	.30
Comorbidities, n (%)							
Hypertension	18	30.00	19	30.65	χ^2	0.01	.94
Diabetes	13	21.67	7	11.29	χ^2	2.40	.12
Coronary heart disease	2	3.33	6	9.68	Fisher	-	.27
Chronic renal failure	3	5.00	0	0.00	Fisher	-	.12
Chronic obstructive pulmonary disease	4	6.67	5	8.01	Fisher	-	.10

venipuncture was completed. We recorded the patients' general information such as sex, age, and blood pressure. Data on chronic disease status known at the time as the most common chronic diseases related to COVID-19 susceptibility and severity were collected (hypertension, diabetes, coronary heart disease, chronic renal failure, chronic obstructive pulmonary disease). Finally, the proceduralist nurse's years of working experience were also recorded. Data were entered initially on a paper form. The form was taken from the isolation ward and entered in the computerized software. One member of the research team entered the data, and a second verified the data entry for accuracy.

STATISTICAL ANALYSIS

The data were entered in the SAS 9.4 software. Ratio and median were used to describe the count data (first attempt success rate and satisfactory score). The mean and SD were used to describe the quantitative data (procedure time). Student *t* test was used to analyze the difference in time taken for venipuncture between the 2 groups. Chi-square test was used to analyze the difference in the success rate of the first venipuncture. The *z* test (Mann-Whitney U test) was used to analyze differences in patients' satisfaction. The 2-tailed α level was set as .05.

ETHICAL CONSIDERATIONS

All patients provided verbal informed consent and voluntarily engaged in this study. The study was approved by the medical ethics committee of the Tongji Hospital Affiliated to Tongji Medical College of Huazhong University of science and technology before implementation (IRB approval number: TJ-C20200157).

Results

SAMPLES AND CHARACTERISTICS OF PARTICIPANTS

A total of 122 patients with COVID-19 were enrolled in the study, which was carried out by 8 nurses (4 nurses in each group). There were 62 patients in the intervention group and 60 patients in the control group. The demographic data for the 122 patients are summarized in Table 1. There were no significant differences between the 2 groups in sex, age, blood pressure, and chronic diseases status.

OUTCOMES

The outcomes measured were the first attempt success rate, total time taken to accomplish a successful PIVC, and patient satisfaction with the procedure. In the intervention group, 57

TABLE 2
Comparison of evaluation index between groups

Index	Control n = 60		Intervention n = 62		Statistics		P value
	Mean, n, or median	SD, %, or IQR	Mean, n, or median	SD, %, or IQR	Test	Value	
Procedure time, s, mean (SD)	388.27	88.97	211.44	68.58	<i>t</i>	12.27	< .001
First attempt success rate, n (%)							
Success	46	76.67	57	91.94	χ^2	5.41	.02
Failure	14	23.33	5	8.06			
Patients' satisfaction degree, score, median (IQR)	6	4-7	7.5	6-9	<i>z</i>	-3.31	< .001

IQR, interquartile range.

cases were successful with a first attempt success rate of 91.94%. In the control group, 46 cases were successful, and the first attempt success rate was 76.67%. The first attempt success rate in the intervention group was significantly higher than that of the control group ($\chi^2 = 5.41$, $P = .02$). In the intervention group, it took an average of 211.44 seconds to complete the PIVC procedure, whereas the time was 388.27 seconds in the control group. The total time taken to complete the PIVC was significantly shorter in the intervention group than the control group ($t = 12.27$, $P < .001$). The patient satisfaction scores in the intervention group were significantly higher than that of the control group (7.5 vs 6, $z = -3.31$, $P < .001$). The results are shown in Table 2.

Discussion

Our results suggest that the use of an infrared vein visualizer for cannulation in patients with severe COVID-19 was effective in increasing the first attempt success rate, reducing total operating time, and improving patients' satisfaction. This provides an important additional method to standard care to facilitate PIVC under COVID-19 isolation conditions.

PIVC is widely used in clinical nursing practice. In some cases, inserting an intravenous cannula can be a challenge even for experienced nursing personnel. Failed cannulation is more likely among children and patients with darker skin tones in which the veins are more difficult to visualize, anxiety, critical illness, and chronic disease.¹¹⁻¹⁵ Older adults and those with complications such as chronic obstructive pulmonary disease, diabetes, hypertension, and heart disease are at an increased risk of COVID-19

infection.¹⁶ These previously documented COVID-19 risks are consistent with our finding that approximately half of the patients suffer from pre-existing chronic diseases. All subjects in our study were severe COVID-19 cases. COVID-19 not only causes physical health declines but also results in a number of psychological complications.¹⁷ One month after hospital discharge, 42% of COVID-19 survivors still suffered from anxiety.¹⁸ Given that chronic disease and patient anxiety are also risk factors for failed PIVC, the PIVC procedure when the proceduralist is wearing personal protective equipment in the COVID-19 isolation ward combines to make the procedure more difficult.

For nurse proceduralists, the special environment of the COVID-19 isolation ward also increased the difficulty of PIVC. In our isolation wards, health care workers must wear protective clothing and goggles, which can slow their actions, extend working time, complicate the assessment of patients' veins, and delay the PIVC insertion procedure. In addition, the nurses were required to put on several layers of rubber gloves in the isolation wards, which made it difficult to palpate the thickness, elasticity, and direction of blood vessels. Thus, longer time was needed for vessel selection for patients in COVID-19 isolation. Once the tourniquet is applied, lengthy periods of time spent on searching for suitable veins can also cause several unwanted effects such as pain, trauma, and subcutaneous bleeding. In the care of patients with COVID-19 in isolation, PIVC is at a high risk of failure at the first attempt. Failure of PIVC not only increases the pain for the patient but may also bring added anxiety and stress to the patient and proceduralist, making subsequent PIVC attempts increasingly challenging. Stevens et al and others have reported that improper venipuncture may lead to peripheral nerve injury

and many other adverse consequences.^{19–21} Walsh²² pointed out that multiple venipuncture attempts can heighten patient anxiety and suffering, delay vital treatment, and increase costs.

For many years, researchers have been investigating the state-of-art venipuncture technologies, and at the same time, various tools, and methods^{23,24} have been developed to improve the success rate of venipuncture in clinical practice. The application of devices to visualize subcutaneous vessels and nerves is particularly useful for novice proceduralists and may improve the success rate in patients requiring special care, such as patients who are elderly, children, or obese, or those with darker skin tones whose veins are difficult to identify with unassisted eyesight or palpation.²⁵

In addition to the infrared device, ultrasound may also be used to assist in the PIVC procedure. The efficacy of ultrasound has been reported; however, ultrasound is expensive and requires substantial skill.²⁶ Our results with an infrared vein visualizer were consistent with the findings of Sun et al⁶ that the application of vein visualizers improved the first attempt success rate and shortened the procedure time. In opposition to our findings, several other studies^{27–29} did not report a benefit to using infrared venous visualization technique in pediatric patients. The difference may be attributed to benefits specific to adult patients with severe COVID-19 in isolation conditions and our exclusion criteria for patients with level 3 veins. This difference may be further explained by the following specific reasons. First, patients varied greatly in disease condition and age. Second, the special COVID-19 isolation environment made traditional PIVC a procedure with a high risk of failure compared with nondisaster clinical conditions. Third, our patients were all Asian with a skin color that varied less than a study sample inclusive of patients who identify as Black, White, Indigenous, Pacific Islander, or multiracial.

In this study, the difference in patients' satisfaction scores between the 2 groups was statistically significant. Venipuncture, as the initial step of intravenous infusion treatment, is an invasive procedure. The failure of venipuncture increases both the pain that patients experience and the pressure for nurses, which can even cause interpersonal tension by potentially creating a decrease in patient trust in the clinical competency of the nurse. In particular, patients with COVID-19 are more likely to be elderly people with poor vascular condition, and the isolation wards further make venipuncture more difficult. By using an infrared vein visualizer, the satisfaction of patients may be significantly improved, thereby supporting a more trusting, therapeutic, and harmonious relationship between patients and nursing staff.

For future research, randomized and controlled trials are recommended to further test the efficacy of infrared

vein visualizers. Such application can also be encouraged in other emergent and/or nonemergent clinical conditions, wherein a high quality of PIVC is demanded.

Limitations

This study had several limitations. First, the sample size was relatively small and collected in 2 units in only 1 Chinese hospital setting. Patients in our sample were not racially diverse. Thus, generalizability may have been limited. Second, owing to the constraint of the disaster conditions, we did not randomize the groups. Third, the nurse proceduralists were required to grasp this new technique in a short period of time under new disaster working conditions. Fourth, we did not collect data on the total number of PIVC attempts per patient.

We also assessed the risk of bias on the basis of the Risk of Bias in Non-randomized Studies of Interventions tool.³⁰ (1) Confounding: The potential confounding bias could result from prognostic variables related to vascular condition. In our study, patients with vein levels of 0 to 2 were included for PIVC. Because of the emergent and isolation condition, further stratification of patients was not conducted. Thus, this may bring bias into the study. (2) Selection bias: The included samples comprised severe COVID-19 cases with yet stable vital signs. Although we had objective inclusion and exclusion criteria, minor bias may still exist. (3) Bias in measurement classification of interventions: The satisfactory score of patients could have been affected by their psychological state and practices unrelated to the PIVC procedure. (4) Bias in measurement of outcomes: The study was carried out by 2 groups of nurses in 2 different isolation wards. Despite standardized training for the nurses, there could have been possible bias regarding intervention fidelity and outcome measurement. Since the study was conducted in a blinded manner and the patients were more than willing to participate in the research, no missing data generated during the study and the bias resulting from intended intervention and selection of reported results could be neglected. Overall, this study had moderate risk of bias compared with a well-performed randomized trial.

Implications for Emergency Clinical Care

Our study has implications for emergency clinical practice. In the emergency department, nurses perform PIVC in a wide variety of patient acuity, age, and isolation conditions. In the case of patients who need urgent intravenous access, if

the vascular condition is poor and the venipuncture is difficult, it may increase nurse workload and stress. Difficult PIVC may delay patient rescue and resuscitation in the ED setting. Under COVID-19 isolation conditions, infrared technology to assist PIVC may improve the success rate at first attempt, decrease procedure time, and increase patient satisfaction with the procedure. We recommend that bedside infrared imaging devices and proceduralist training to use the devices be made available to emergency nurses caring for adult patients who require COVID-19 isolation.

Conclusion

Nurses may encounter difficulty when performing PIVC under disaster and COVID-19 isolation conditions. The application of infrared venipuncture assistive technology in patients with COVID-19 could improve the first attempt success rate, shorten the total procedure time, and enhance patients' satisfaction.

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