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RESEARCH

The effect of using vein visualization devices to facilitate peripheral intravenous cannulation on pain, fear, and patient satisfaction in adult oncology patients: a randomized controlled trial

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Abstract

Objective To investigate the effect of vascular imaging using near-infrared (NIR) light and transilluminator devices on pain, fear of pain, and patient satisfaction during peripheral intravenous cannulation (PIVC) insertion.

Methods NIR light visualization ($n = 50$) and transilluminator ($n = 50$) techniques were used in the intervention, while the standard method was used in the control group ($n = 52$). The primary outcome was the success rate of first-attempt PIVC insertion, pain, and fear of pain with the PIVC procedure. Secondary outcomes included patient satisfaction and duration of cannulation.

Results The rate of successful first-attempt cannulation was 90% in the NIR light group, 70% in the transilluminator group, and 96.2% in the control group. No statistically significant difference was observed between the intensities of PIVC pain and fear of PIVC insertion pain between the groups. NIR light and control group participants' satisfaction and overall experience of PIVC insertion scores were higher than transilluminator participants. The PIVC procedure length of time for the transilluminator group (43.88 ± 10.5 s) participants was higher than that of the NIR light (29.06 ± 11.52 s) and control group (27.19 ± 14.83 s) participants ($p < 0.05$).

Conclusions The difference obtained in the study did not reveal a significant enough difference to determine the best method to reduce pain and fear of pain. Additionally, regarding patient satisfaction, participants in the NIR light and control groups reported higher satisfaction levels than the transilluminator group. The transilluminator group had the longest PIVC procedure. Vein visibility scores differed significantly among the groups, with higher visibility observed in the NIR light and control groups than in the transilluminator group.

Trial registration The trial was prospectively registered at the ClinicalTrials.gov Protocol Registration and Results System (ClinicalTrials.gov ID: NCT05892978) on June 6, 2023, and received approval from the Non-Interventional Clinical Research Ethics Committee of Bursa Uludag University Faculty of Medicine (Approval no: 2023-11/42 date: May 16, 2023).

Keywords Catheterization · Fear of pain · Pain · Patient satisfaction · Vascular access efficiencies · Vein viewer

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Introduction

Prolonged cycles of antineoplastic therapy in adult oncology patients lead to endothelial dysfunction in veins, loss of vasodilatory effect, and suppression of anti-inflammatory and vascular repair functions [1]. Moreover, the extreme pH and osmolarity of chemotherapy drugs (vesicants, irritants) can cause extravasation, defined as the inadvertent leakage of medications into surrounding tissue. This process can sometimes result in complications such as tissue necrosis or skin injury [2], pain, urticaria, erythema, ecchymosis, thrombophlebitis, and septicaemia [3]. Activation of the sympathetic nervous system induces vasoconstriction, which

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decreases venous fullness and may subsequently cause pain, redness, ulceration, and necrosis along the vein [4]. These factors collectively lead to vasoconstriction, reduced venous fullness, and progressive depletion of accessible veins, making peripheral intravenous cannulation (PIVC) increasingly difficult for nurses throughout the treatment trajectory [5, 6].

Repeated unsuccessful cannulation attempts not only prolong the procedure and compromise the efficiency of vascular access but also intensify patients' pain perception, procedural anxiety, and fear responses [7, 8]. In oncology settings, where individuals are already burdened by the psychological distress of a cancer diagnosis, invasive interventions such as PIVC further exacerbate traumatic experiences, increase dissatisfaction with care, and may even jeopardize adherence to treatment regimens [8]. Consequently, venous access difficulty should be understood not merely as a technical or procedural challenge for healthcare providers, but as a multidimensional clinical problem with direct implications for patient comfort, psychological well-being, quality of life, and continuity of therapy [9]. Against this backdrop, the present study deliberately prioritized pain and fear of pain as the primary outcomes, since these parameters most directly capture the patient-centered consequences of vascular access procedures and provide a clinically meaningful perspective that extends beyond traditional measures of procedural success. Pharmacological and non-pharmacological strategies have been used to reduce pain during peripheral cannulation. Aromatherapy [10], ShotBlocker® [11], valsalva maneuver [12], virtual reality application [13], distraction [14], local hot application [15], and local cold application [16] can be listed among the non-pharmacological methods. Pharmacological methods to reduce pain during cannulation include local anaesthetic injection with microneedle [17] and topical anaesthetic application [18]. However, pain is not only a physical sensation but also a psychological experience [19]. The level of fear and dissatisfaction with pain, especially in cancer patients, may increase the intensity of pain felt during the procedure [8].

Understanding "algophobia" underscores the clinical significance of the interplay between pain and fear, which is particularly relevant when evaluating patients' procedural experiences [19]. Algophobia means fear of pain, excessive fear of pain, excessive fear of painful sensations, and everything that may cause this sensation [20]. Fear of pain is a pain-related condition and can be defined as a set of verbal behavioral and physiological reactions to actual or potential pain [21]. Furthermore, pain and fear of pain can trigger an autonomic response, leading to vasoconstriction [22]. This can complicate the cannulation process, resulting in multiple attempts to obtain vascular access and increasing the risk of infection and other related complications [23]. Therefore, controlling patient pain, increasing patient satisfaction, and minimizing pain-related complications play critical roles in patients receiving chemotherapy. However, the difficulties experienced during PIVC insertion with traditional methods make the insertion process difficult for nurses and increase pain and anxiety for patients [24]. Hence, the use of more effective vascular imaging techniques may reduce pain and fear of pain by facilitating the catheterization process, leading to increased patient satisfaction.

This study aimed to investigate the effect of vascular imaging using near-infrared (NIR) light and transilluminator devices compared with a standard practice control group on pain, fear of pain, and patient satisfaction during PIVC insertion. In this context, two important questions were discussed:

Does the use of three different methods to facilitate PIVC insertion in adult oncology patients result in significant differences in the levels of pain and fear of pain experienced by patients?

Does the use of three different methods to facilitate PIVC insertion in adult oncology patients result in significant differences in patient satisfaction?

Methodology

Study design

This study was conducted in Türkiye as a three-armed, single-center, single-blinded (data analysts), randomized controlled trial comparing three conditions: NIR light (vascular imaging device with NIR light in the intervention 1 group), transilluminator (vascular imaging device with transilluminator in the intervention 2 group), and a control group (standard-of-care). The Consolidated Standards of Reporting Trials (CONSORT) standards for randomized trials of non-pharmacological treatments were followed [25]. The study was prospectively registered in the ClinicalTrials.gov Protocol Registration and Results System (PRS) before starting data collection with the first participant (ClinicalTrials.gov ID: NCT05892978).

Study setting and population

The study was conducted in patients admitted to the Chemotherapy Unit within the Oncology Outpatient Clinic of the Department of Oncology in a tertiary care hospital from June 17 to December 31, 2023.

Inclusion and exclusion criteria

The inclusion criteria were as follows: patients over 18 years of age; without peripheral vascular disease; not receiving anticoagulant therapy; without signs of extravasation, infiltration, or phlebitis; without acute trauma, inflammation, ecchymosis, hematoma, scar tissue, edema, metal prosthesis, or paralysis around the extremity to be cannulated; without mastectomy; without communication problems; and with a mental level suitable for participation in the study.

The exclusion criteria were as follows: patients receiving chemotherapy treatment for the first time; with peripheral vascular disease; with complications after a previous cannulation procedure; who have had a mastectomy; with acute trauma, inflammation, ecchymosis, hematoma, scar tissue, edema, metal prosthesis, or paralysis around the extremity to be cannulated.

Sample size calculation

Information from Çağlar et al. [26] was used as input for the power analysis. Phi (Φ), an effect size indicator, was calculated as 0.448. Using the medium effect size obtained from the reference study, the minimum sample size was calculated as $n = 138$ to reach an 80% power level when the type I error level was accepted as 5%. Considering possible losses, the sample size was taken as $n = 140$. Regarding multiple comparisons, the initial sample size calculation did not incorporate a Bonferroni correction. However, to ensure sufficient statistical power despite potential inflation of type I error, the authors recruited a larger sample than the minimum required by power analysis. The G*Power program was used for power analysis [27]. The study was completed with 152 chemotherapy-treated patients, 50 in the intervention groups 1 and 2, and 52 in the control group (Fig. 1).

Randomization

Random allocation was prepared by a statistician through envelopes used in a lottery method. Each envelope was sequentially numbered and identified to form three groups: Intervention 1, Intervention 2, and control. Thus, the participants were divided into groups: (Group 1) vascular imaging with NIR light, (Group 2) imaging with a transilluminator, (Group 3) control group. No stratification by vein visibility was implemented. The study employed a 1:1:1 allocation ratio across three groups (NIR light, transilluminator, control). The random allocation sequence was generated by the co-investigator, who also supervised the envelope opening, while the principal investigator remained blinded to group assignments to ensure allocation concealment. Due to the nature of the interventions, blinding of the nurse/operator performing PIVC insertion was not feasible, as both devices were visibly distinct. Data analysts remained blind to group allocation, with study groups numerically coded during analysis. It is acknowledged that the impossibility of operator blinding may introduce performance bias, including potential differences in technique or unconscious preferences. To mitigate this risk, all PIVC insertions were performed by a single, experienced researcher using a standardized protocol.

Intervention

Vascular imaging group with NIR light

Before cannulation, participants were evaluated at the beginning of their chemotherapy courses. Before potential vascular damage from treatment, vital signs, skin color, skin turgor, and vein visibility were assessed and recorded. The stopwatch started as soon as the tourniquet was secured, and vein visibility was re-evaluated by the nurse researcher using a NIR light vascular imaging device. The time measurement did not include the preparation of the necessary materials. The procedure time was recorded from the initial skin puncture until the appearance of blood flashback in the catheter chamber, which was considered the endpoint of successful cannulation. If no blood flashback was observed, the attempt was considered unsuccessful. In the event of failure, the researcher was allowed a maximum of three PIVC attempts per patient. The intensity of pain and fear of pain was assessed and recorded before, during, and after the procedure across three repeated measurements. After the completion of the procedure, the participants were asked questions to measure their satisfaction level, and their responses were recorded. All catheters used in this study were standard short-term peripheral intravenous cannulas (22-gauge, 25 mm [1 inch] in length); none was a long-term device, such as a peripherally inserted central catheter (PICC line).

Vascular imaging group with transilluminator

All procedures were repeated exactly. A transilluminator was used as an imaging device instead of NIR light.

Control group

Again, all procedures were repeated exactly. The control group underwent the standard PIVC insertion procedure without the use of any vascular imaging device.

Instruments

Personal descriptive form

A researcher-administered personal descriptive form developed by the investigators was used to record participants' demographic and clinical characteristics developed by the researchers, consisting of questions regarding the patients'

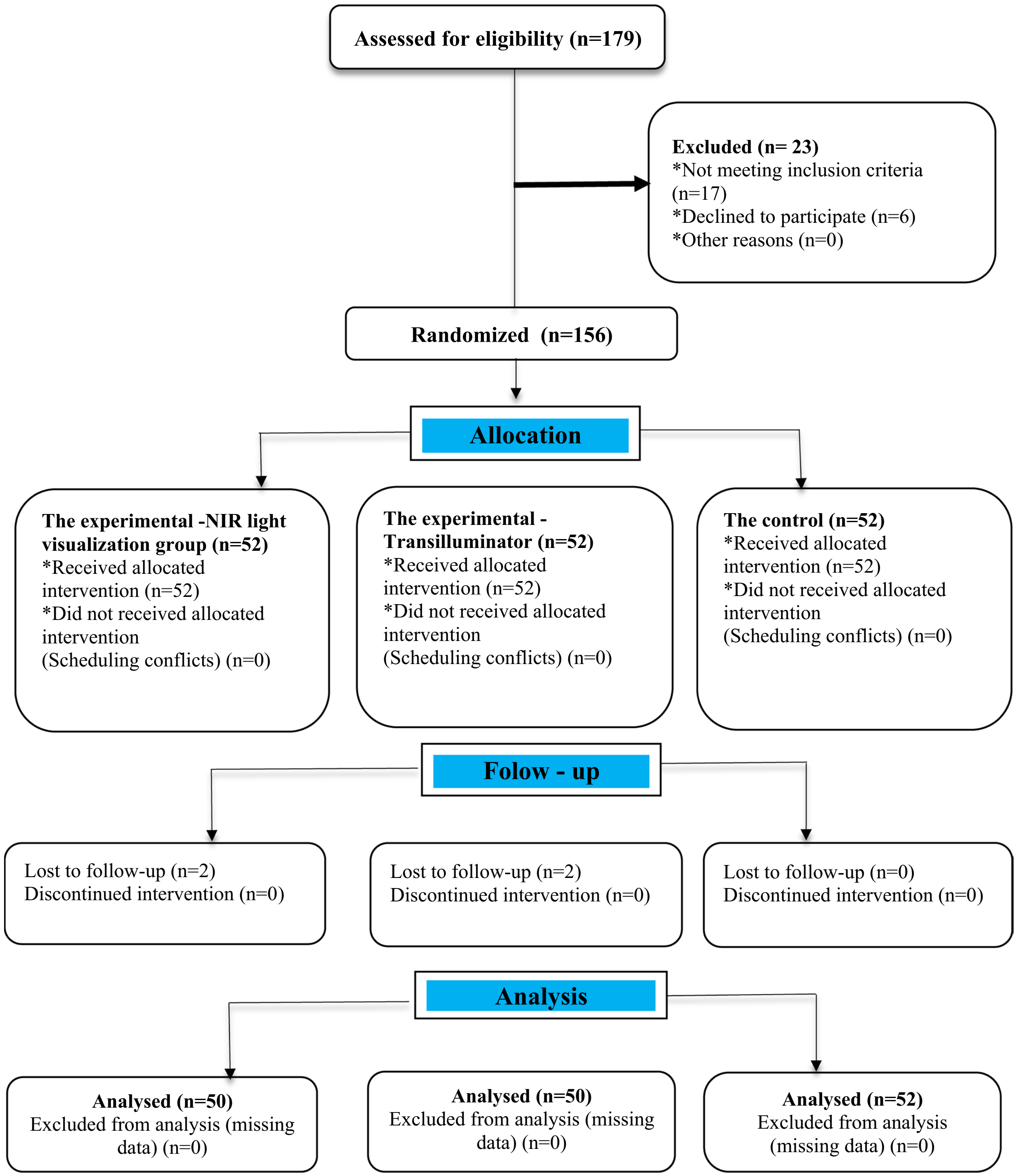

Fig. 1 CONSORT flow diagram of the study

demographic data, including gender, body mass index, skin turgor, skin color, cancer type, blood pressure, body temperature, and history of intravenous cannulation. Skin turgor was assessed manually, and skin color was assessed by the Fitzpatrick skin type scale [28].

Visibility of the veins

Vein visibility was assessed using a five-step Likert-type scale ranging from 1 (poorly visible) to 5 (clearly visible) [29, 30]. Participants are evaluated using this scale: 1 = no veins visible or palpable, 2 = visible but not palpable, 3 = barely visible and palpable veins, 4 = visible and palpable veins, and 5 = clearly visible and easily palpable veins.

Measurement and recording of the pain perception variables by the nurse

Patients were asked to rate their pain intensity using a visual analog scale (VAS) before, during, and after the PIVC insertion procedure by marking a 10 cm ruler, indicating "no pain" on one end and "intolerable pain" on the other end [31].

Measurement and recording of the fear perception variables by the nurse

Patients were asked to indicate the level of fear they felt before, during, and after the PIVC insertion on a 10-cm visual analog scale (VAS), ranging from 0 ("no fear of pain") to 10 ("extreme fear of pain"). In addition, 14 questions aligned with the literature [8, 19, 32] were prepared by the researchers. Five experts, consisting of three nurse academicians and two physicians, reviewed the questionnaire prior to the study. In the evaluation of the opinions received from the experts, the content validity index (CVI) was determined as 1.00. In addition, internal consistency reliability was assessed using Cronbach's α, yielding $\alpha = 0.91$. The questions consisted of fearful situations in PIVC placement, questions about fear of pain during the invasive procedures, and situations experienced after chemotherapy (Table 3).

Measurement and recording of the satisfaction variables by the nurse

Patients were asked to mark their satisfaction level during the PIVC placement procedure on a 10-cm ruler with the words "very satisfied" on one end and "very dissatisfied" on the other. Also, seven questions aligned with the literature [9, 33] were prepared by the researchers. Five experts, consisting of three nurse academicians and two physicians, reviewed the questionnaire before the study. In the evaluation of the opinions received from the experts, the CVI was determined as 1.00. In addition, internal consistency reliability was assessed using Cronbach's α, yielding $\alpha = 0.88$. The questionnaire included items evaluating patient preferences for future PIVC insertions, overall satisfaction with the procedure, satisfaction with the nurse's PIVC insertion skills, the patient's previous experiences with PIVC access, whether the patient considered herself/himself to have a history of difficult vascular access, and whether the nurse conducted a comprehensive assessment of the patient's veins before insertion.

Development of study questionnaire

Before data collection, a preliminary pilot evaluation was conducted with approximately 10% of the target sample to assess the readability, clarity, and comprehensibility of the study questionnaire. Based on participant feedback, minor wording adjustments were made to improve clarity. These revisions were reviewed by the research team but were not subjected to a second pilot test, as the changes were minimal. To assess the test–retest reliability of the questionnaire, it was re-administered to the same pilot participants 3 to 5 days later by the same researcher using a face-to-face interview technique. Data from this pilot phase were excluded from the main statistical analyses.

Outcome assessment

The primary outcome measures of this study were cannulation success and patient-reported pain and fear of pain. Secondary outcome measures included patient satisfaction and duration of cannulation. No modifications were made to the study protocol or measurement tools after initiation.

Statistical analysis

The data obtained in the study were analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics (number, percentage, minimum–maximum values, mean, and standard deviation) were used to summarize the data. The normality of quantitative data was assessed using the Kolmogorov–Smirnov test. For non-normally distributed data, comparisons of more than two independent groups were performed using the Kruskal–Wallis *H* test, and comparisons of more than two dependent measurements were performed using the Friedman test. When significant differences were detected, post hoc analyses with Bonferroni correction were conducted to identify differing groups. Categorical data were analyzed using the chi-square or Fisher's exact tests, as appropriate. Statistical significance was set at $p < 0.05$, and nonparametric tests were applied for hypothesis testing.

Ethical considerations

The study was approved by the Non-Interventional Clinical Research Ethics Committee of Bursa Uludag University Faculty of Medicine (Approval no: 2023-11/42 date: May 16, 2023). Written institutional permission (Approval no: E-73115338-000-89396) was obtained from the hospital where the study was conducted. Participants were informed that participation in the study was completely voluntary. Prior to participation in the study, all patients were informed about the research process and were asked to sign the consent form. It was also explained that they had the right to refuse to participate in the study or withdraw from the study at any time. The study was conducted in accordance with the principles stated in the Declaration of Helsinki.

Results

Primary outcome

Participants' characteristics

No significant differences were observed among groups of the participants regarding gender, skin turgor, Fitzpatrick skin type, and time since last PIVC insertion ($p > 0.05$). The cancer diagnosis and actively used hand (right/left) distributions according to the groups of the participants were significant ($p < 0.05$). It was observed that the distribution of the participants' vein visibility graded by the researcher before and after tourniquet tying was significant ($p < 0.05$). After applying the tourniquet, vein visibility was assessed using the established vein visibility score. In the NIR light group, 4% of participants were scored as 1 st, 50% as 2nd, 34% as 4th, and 12% as 5th. In the transilluminator group, 4% were scored as 1 st, 30% as 2nd, 48% as 3rd, 14% as 4th, and 4% as 5th. In the control group, 28.8% were scored as 2nd, 11.5% as 3rd, 38.5% as 4th, and 21.2% as 5th. First-attempt success rates during PIVC insertion were compared among the three study groups. A statistically significant difference was observed among the participant groups ($p < 0.05$) (Table 1). First-attempt success rates for PIVC insertion were 90% in the NIR light group, 70% in the transilluminator group, and 96.2% in the control group.

Pain and fear of pain PIVC insertion scores

No statistically significant intergroup differences were found in PIVC-related pain intensity or fear of pain ($p > 0.05$). However, within-group analyses across three time points (before, during, and after insertion) showed significant temporal changes ($p < 0.05$, Friedman test). Post hoc Bonferroni analyses indicated that pain intensity was higher during PIVC insertion than before and after in the NIR group. In contrast, in the transilluminator and control groups, pain intensity was higher before and during than after ($p < 0.05$). Regarding fear, the NIR and control groups reported higher levels before and during PIVC insertion than after. In contrast, the transilluminator group reported higher levels only before than after the procedure ($p < 0.05$) (Table 2).

The distribution of the vein area where PIVC insertion was performed was not significant across the groups ($p > 0.05$) (Table 3). However, the number of PIVC insertions differed significantly between groups ($p < 0.05$): one venipuncture was sufficient for 96.2% of the control group, 90% of the NIR light group, and 70% of the transilluminator group. Regarding fear of the procedure, 36% of the NIR light group reported fear, the lowest proportion among the groups ($p > 0.05$). When the analysis of the participants' pain fear levels for PIVC insertion was examined, it was determined that 28% of the participants in the NIR light group answered yes, representing the lowest percentage rate ($p > 0.05$). Finally, preferences for the same method in future interventions differed significantly ($p < 0.05$): 90.4% of the control group, 78% of the NIR light group, and 22% of the transilluminator group stated they would prefer the same method again.

Secondary outcome

Statistically significant differences were found among the groups in terms of satisfaction level, overall experience of PIVC insertion, pain perception, and procedure time ($p < 0.05$). Post hoc Bonferroni analysis indicated that satisfaction and overall experience scores were significantly higher in the NIR light and control groups compared to the transilluminator group. Participants in the control group perceived PIVC insertion as painful compared to those in the NIR light and transilluminator groups. In addition, procedure times were significantly longer in the transilluminator group than in the NIR light and control groups ($p < 0.05$) (Table 4).

Discussion

This study aimed to compare three different methods used to facilitate PIVC insertion in adult oncology patients in terms of the pain and fear of pain experienced by the patients and the level of satisfaction to determine whether one is more effective than the other. However, the difference obtained in the study did not reveal a significant enough difference to determine the best method to reduce pain and fear of pain. Additionally, in terms of patient satisfaction, participants in the NIR light and control groups reported higher levels of satisfaction compared to the transilluminator group.

Reduced visibility of veins in patients receiving chemotherapy is influenced by several interrelated factors, including the physical condition of the veins, the nature of the chemotherapy agents used, and the cumulative effects of repeated treatments. In one study, the visibility of veins in 59.3% of patients was measured as 0 mm on the 63rd day of chemotherapy treatment [5]. Examining the studies on NIR light vascular imaging, it was reported that the visibility of veins increased, and visibility improved [34, 35]. In one study, it was found that the use of NIR light increased the visibility of veins by four times in obese participants and by three times in morbidly obese participants compared to

Table 1 Demographic and clinical characteristics of participants ($N=152$)

Characteristics		Intervention group; near-infrared light	Intervention group; transillumi-nator	Control group		
		n(%)	***n*** (%)	***n*** (%)	χ^2	*p*-value
Gender	Female	29 (58.0)	31 (62.00)	27 (51.90)	1.075	.584
	Male	21 (42.00)	19 (38.00)	25 (48.10)		
Skin turgor	Poor	10 (20.00)	7 (14.00)	11 (21.20)	0.992	.609
	Regular	40 (80.00)	43 (86.00)	41 (78.80)		
Fitzpatrick skin typing	Type 2	4 (8.00)	4 (8.00)	5 (9.60)		
	Type 3	28 (56.00)	24 (48.00)	24 (46.20)	9.273	.159
	Type 4	16 (32.00)	16 (32.00)	23 (44.20)		
	Type 5	2 (4.00)	6 (12.00)	-		
Type of cancer	Lung	19 (38.00)	15 (30.00)	23 (44.20)		
	Breast	13 (26.00)	17 (34.00)	14 (26.90)		
	Head and neck	6 (12.00)	3 (6.00)	1 (1.90)	27.502	.017*
	Urogenital	3 (6.00)	4 (8.00)	12 (23.10)		
	Skin tumors	3 (6.00)	2 (4.00)	1 (1.90)		
	Gastrointestinal	1 (2.00)	1 (2.00)	-		
	soft tissue sarcoma	3 (6.00)	8 (16.00)	-		
	Neuroendocrine tumors	2 (4.00)	-	-		
Active hand	Right	43 (86.00)	44 (88.00)	51 (98.10)	11.888	.018*
	Left	7 (14.00)	3 (6.00)	1 (1.90)		
	Mixed	-	3 (6.00)	-		
Duration of last PIVC insertion	12–24 h before	1 (2.00)	5 (10.00)	1 (1.90)		
	1–3 days	2 (4.00)	1 (2.00)	4 (7.70)	8.630	.195
	4–7 days	11 (22.00)	13 (26.00)	8 (15.40)		
	More than 1 week	36 (72.00)	31 (62.00)	39 (75.00)		
Visibility of the vein before the tourniquet is applied (nurse assessment)	1st	8 (16.00)	20 (40.00)	15 (28.80)		
	2nd	30 (60.00)	13 (26.00)	23 (44.20)		
	3rd	-	14 (28.00)	3 (5.80)	36.856	.000*
	4th	12 (24.00)	3 (6.00)	11 (21.20)		
	5th	-	-	-		
Visibility of the vein after the tourniquet is applied (nurse assessment)	1st	2 (4.00)	2 (4.00)	-		
	2nd	25 (50.00)	15 (30.00)	15 (28.80)		
	3rd	-	24 (48.00)	6 (11.50)		
	4th	17 (34.00)	7 (14.00)	20 (38.50)	49.837	.000*
	5th	6 (12.00)	2 (4.00)	11 (21.20)		
Successful of the first PIVC insertion		45 (90.00)	15 (70.00)	50 (96.20)	18.600	.000*
Unsuccessful of the first PIVC insertion		5 (10.00)	35 (30.00)	2 (3.80)		
Total		50 (100.00)	50 (100.00)	52 (100.00)		

Visibility of the vein: 1st grade: veins not visible or palpable, 2nd grade: veins visible but not palpable, 3rd grade: veins barely visible and palpable, 4th grade: veins visible and palpable, 5th grade: veins clearly visible and easily palpable; χ^2 test: chi-square tests

[*] $p<.05$

the traditional method. The same study found that African American participants had better visibility of veins than the control group [34]. In another study, the effects of fist clenching and closing, NIR light, and standard methods on the visibility of veins in oncology patients receiving chemotherapy were examined. The rate of the visibility of veins was found to be 35.6% in the NIR light and standard groups and 11.11% in the fist clenching group [33]. Similar to the literature, the results of the present study also revealed that the 4th degree visibility of veins was 34% and 38.5% in the NIR light and control groups, respectively, while it was 14% in the transilluminator group. However, in contrast to the results of the present study, one study reported that all infants and children were able to visualize the veins above

Table 2 Comparison of the pain and fear of PIVC pain scores of the participants according to the groups ($N=152$)

		Intervention group; near-infrared light (*n* = 50)		Intervention group; transil-luminator (*n* = 50)		Control group (*n* = 52)			
		Min–max	$\overline{X} \pm$ SD	Min–max	$\overline{X} \pm$ SD	Min–max	$\overline{X} \pm$ SD	***H***	***p-value***
Pain severity	Before[a]	1.00–10.00	2.48 ± 2.41	1.00–10.00	3.22 ± 2.76	1.00–10.00	2.46 ± 2.37	4.332	.115
	During[b]	1.00–10.00	3.44 ± 2.74	1.00–9.00	2.98 ± 1.89	1.00–10.00	3.62 ± 2.83	0.199	.905
	After[c]	1.00–10.00	1.66 ± 1.6	1.00–8.00	1.46 ± 1.22	1.00–6.00	1.5 ± 1.21	0.897	.639
Friedman test		33.389		34.102		35.097			
p		.000*		.000*		.000*			
Post hoc		b > a, c		a, b > c		a, b > c			
Fear of pain PIVC severity	Before[a]	1.00–10.00	3.1 ± 3.18	1.00–10.00	3.22 ± 2.71	1.00–10.00	3.48 ± 3.24	1.170	.557
	During[b]	1.00–10.00	3.04 ± 3.26	1.00–10.00	2.52 ± 2.32	1.00–10.00	3.17 ± 3.19	0.410	.814
	After[c]	1.00–10.00	1.42 ± 1.8	1.00–10.00	1.8 ± 2.22	1.00–10.00	1.6 ± 1.74	1.996	.369
Friedman test		30.804		20.602		23.227			
p		.000*		.000*		.000*			
Post hoc		a, b > c		a, b > c		a, b > c			

H Kruskal–Wallis *H* test, $\overline{X} \pm$ SD: Mean ± standard deviation

[a]before PIVC insertion

[b]during PIVC insertion

[c]after PIVC insertion

*$p < .05$

the hand with the use of NIR light, but the veins in the antecubital fossa could not be visualized in four patients [36]. In another study, one of three nurse operators working in the emergency department reported that NIR light made venipuncture more difficult during PIVC insertion [37]. The difference between the results may be due to population differences such as pediatric patients, adult patients presenting to the emergency department, and patients receiving chemotherapy treatment. This discrepancy may also be attributable to the use of different versions of the NIR light device across studies.

Pain and fear assessment

Pain and fear are among the most common and distressing symptoms in patients receiving chemotherapy [38]. In the present study, no significant differences were observed between the groups regarding pain intensity or fear of pain. Although using vascular imaging with NIR light or a transilluminator may influence pain scores at different stages of the procedure (before, during, and after PIVC insertion), these methods do not appear to reduce overall pain. Similar to the current result, two different randomized controlled trials have shown that NIR light has no effect on pain in adult patients admitted to the emergency department [32, 37]. On the other hand, a study of 450 patients diagnosed with hemophilia found that NIR light reduced pain in patients with a history of difficult vascular access but had no effect on pain in patients with easy vascular access [39]. According to Çağlar et al., NIR light was more effective than transilluminator vascular imaging in reducing pain during PIVC insertion in preterm infants [26]. Additionally, other studies have found that the use of NIR light in the pediatric population, especially in patients younger than 3 years of age, reduces pain [40, 41]. Conversely, there are studies suggesting that the use of NIR light in the pediatric population does not improve the pain felt [42, 43]. Based on these results, NIR light is more effective in reducing pain in the pediatric population than in adults. This difference may be attributable to two factors: first, NIR light may act as a distracting device in children; second, the assessment of pain intensity is inherently subjective in both populations.

Multiple unsuccessful attempts to gain venous access have been reported to increase pain and fear in patients [44]. In the present study, 36% of the NIR light, 38% of the transilluminator, and 46.2% of the control group participants reported experiencing fear during PIVC insertion. It was observed that the severity of fear tended to be lower in the groups using the vascular imaging device compared to the control group; however, these reductions were not statistically significant. In the literature, similar to the current study result, it has been stated that although the fear of the procedure is lower in the NIR light group in adult patients admitted to the emergency department, it may not be appropriate to use it to reduce fear [32]. This similarity may be attributed to the high first-attempt success rates of PIVC insertion across all groups, as successful cannulation on the first attempt is generally associated with

Table 3 Comparison of participants' fear and fear of pain related to PIVC insertion according to the groups

Questions			Intervention group; near-infra-red light *n* (%)	Intervention group; transillu-minator *n* (%)	Control group *n* (%)	χ^2	*p*-value
The vein where the PIVC insertion was performed	Dorsal metacarpal vein		9 (18.00)	(16.0)	15 (28.80)	8.743	.068
	Cephalic vein		15 (30.00)	8 (50.00)	22 (42.30)		
	Basilic vein		26 (52.00)	25 (34.00)	15 (28.80)		
Number of the PIVC insertion	One		45 (90.00)	15 (70.00)	50 (96.20)	18.697	.000*
	Two		4 (8.00)	35 (30.00)	2 (3.80)		
	Three		1 (2.00)	-	-		
Do you fear of the PIVC insertion?	Yes		18 (36.00)	19 (38.00)	24 (46.20)	1.235	.539
	No		32 (64.00)	31 (62.00)	28 (53.80)		
Situations after PIVC insertion during chemotherapy infusion	Fainting	Yes	2 (4.00)	2 (4.00)	1 (1.90)	0.464	.793
		No	48 (96.00)	48 (96.00)	51 (98.10)		
	Crying	Yes	1 (2.00)	1(2.00)	-	1.054	.590
		No	49 (98.00)	49 (98.00)	52 (100.00)		
	Palpitations	Yes	4 (8.00)	7 (14.00)	6 (11.50)	0.916	.633
		No	46 (92.00)	43 (86.00)	46 (88.50)		
	Nausea	Yes	-	3 (6.00)	5 (9.60)	4.808	.090
		No	50 (100.00)	47 (94.00)	47 (90.40)		
	Dizziness	Yes	1 (2.00)	2 (4.00)	-	2.108	.348
		No	49 (98.00)	48 (96.00)	52 (100.00)		
	Loss of consciousness	Yes	-	1 (2.00)	-	2.054	.358
		No	50 (100.00)	49 (98.00)	52 (100.00)		
Frightening situations regarding PIVC insertion	Pain	Yes	16 (32.00)	22 (44.00)	26 (50.00)	3.498	.174
		No	34 (68.00)	28 (56.00)	26 (50.00)		
	Explanations of nurse's	Yes	10 (20.00)	12 (24.00)	15 (28.80)	1.088	.580
		No	40 (80.00)	38 (76.00)	37 (71.20)		
	Observing the branule	Yes	13 (26.00)	8 (16.00)	22 (42.30)	8.889	.012*
		No	37 (74.00)	42 (84.00)	30 (57.70)		
	Observing the needle's size	Yes	25 (50.00)	27 (54.00)	27 (51.90)	0.160	.923
		No	25 (50.00)	23 (46.10)	25 (48.10)		
	Observing the PIVC insertion done to others	Yes	11 (22.00)	12 (24.00)	15 (28.80)	0.677	.713
		No	39 (78.00)	38 (76.00)	37 (71.20)		
	Previous bad experiences with PIVC insertion	Yes	21 (42.00)	31 (62.00)	31 (59.60)	4.835	.089
		No	29 (58.00)	19 (38.00)	21 (49.40)		
Fear of pain during PIVC insertion	Yes		14 (28.00)	18 (36.00)	25 (48.10)	4.455	.108
	No		36 (72.00)	32 (64.00)	27 (51.90)		
Preferring this intervention in subsequent PIVC insertion	Yes		39 (78.00)	11 (22.00)	47 (90.40)	58.115	.000*
	No		11 (22.00)	39 (78.00)	5 (9.60)		
Total			50 (100.0)	50 (100.0)	52 (100.0)		

χ^2 test: chi-square tests

* $p<.05$

reduced fear and anxiety. In the current study, the relatively low baseline levels of pain and fear of pain across all groups may have limited the potential for detecting further decreases after the intervention. This phenomenon, often referred to as a "floor effect," occurs when initial scores are already near the minimum value of a measurement scale, leaving little room for improvement. It is also possible that procedural pain is more closely related to the number of PIVC attempts rather than the imaging method used. It is also possible that procedural pain is more closely related to the number of PIVC attempts than the imaging method.

Table 4 Comparison of the participants' satisfaction PIVC insertion according to the groups ($N = 152$)

	Intervention group; near-infrared light ($n = 50$)		Intervention group; transilluminator ($n = 50$)		Control group ($n = 52$)				
	Min–max	$\overline{X} \pm$ SD	Min–max	$\overline{X} \pm$ SD	Min–max	$\overline{X} \pm$ SD	***H***	*p*-value	Post hoc
How would you rate the satisfaction level of PIVC insertion?	3.00–10.00	8.82 ± 2.23	0.00–10.00	6.2 ± 2.74	4.00–10.00	9.35 ± 1.12	51.177	.000*	1,3 > 2
How would you rate the skill of the nurse starting PIVC insertion?	6.00–10.00	9.7 ± 0.79	2.00–10.00	9.48 ± 1.43	5.00–10.00	9.62 ± 0.95	0.431	.806	-
How would you rate your overall experience of PIVC access?	5.00–10.00	9.72 ± 0.93	1.00–10.00	7.4 ± 2.43	1.00–10.00	9.08 ± 1.8	42.411	.000*	1,3 > 2
Would you describe yourself as having difficult intravenous access?	1.00–10.00	4.6 ± 3.5	1.00–10.00	5.56 ± 3.26	1.00–10.00	5.81 ± 3.02	3.099	.212	-
Did the nurse start your PIVC complete thorough look at your veins?	1.00–10.00	9.58 ± 1.65	1.00–10.00	9.38 ± 1.65	5.00–10.00	9.71 ± 0.94	2.069	.355	-
Would you consider PIVC insertion a painful procedure?	1.00–10.00	3.8 ± 3.0	1.00–10.00	3.66 ± 2.68	1.00–10.00	5.54 ± 3.3	9.575	.008*	1 > 2,3
Duration of PIVC insertion	2.00–56.00	29.06 ± 11.52	27.00—66.00	43.88 ± 10.5	10.00–93.00	27.19 ± 14.83	48.292	.000*	2 > 1,3

The time is calculated in seconds

H Kruskal–Wallis *H* test, ±SD: mean ± standard deviation

*$p < .05$

[1] Intervention group near infrared light

[2] Intervention group transilluminator

[3] Control group

Patient satisfaction assessment

Patient satisfaction levels may decrease as the number and duration of invasive attempts for catheter placement increase [45]. In the current study, the control and NIR light groups demonstrated significantly fewer and shorter attempts for successful catheterization, which was accompanied by higher participant satisfaction levels compared with the transilluminator group. In another randomized controlled trial conducted with pediatric hematology–oncology patients, the NIR light group reported higher levels of satisfaction compared with the control group, in which standard venipuncture techniques were used [9]. The positive differences obtained in studies using NIR light may be explained by the shorter time to successful PIVC placement and fewer invasive procedures required. In the present study, the mean satisfaction level of the participants in the transilluminator group was significantly lower compared to the control and NIR light groups. This difference may be explained by the fact that NIR light penetrates the tissues and provides a clearer vascular image, whereas transilluminator devices have limited light spread and contrast, which can prolong the time to locate the vessel and increase the number of failed attempts [39, 46].

Contrary to the findings of the current study, some studies have reported that the use of NIR light increases patient satisfaction compared with standard venipuncture techniques. In another study, participant satisfaction levels in oncology patients receiving chemotherapy were found to be significantly higher in the NIR light group compared to the control group and fist clenching group [33]. Likewise, in patients with severe acute respiratory syndrome coronavirus infection, the satisfaction level in the NIR light group was significantly higher compared to the control group [46]. This difference may be because NIR light was compared only with the control group or alternative techniques in some studies (e.g., fist squeeze method). In the present study, an additional vascular imaging method, the transilluminator, was used. Maintaining the light at the optimal angle and ensuring adequate illumination required additional operator skill during its application. This may have contributed to longer procedure times and a higher number of unsuccessful attempts, which may have led to lower patient satisfaction in the transilluminator group.

Limitations

This study was conducted exclusively in patients receiving chemotherapy at a tertiary care hospital in Türkiye, limiting the findings' generalizability. Moreover, the participant population was racially homogeneous, so the results may not be directly applicable to other ethnic groups. Although all assessment tools were pre-validated for content, further validation in diverse contexts and populations is warranted to strengthen their applicability. The panel used for content validation was limited in size and composition. While five experts were deemed sufficient for preliminary validation, including a more heterogeneous panel—including oncologists, psychologists, and patient representatives—could have further enhanced content validity. Blinding was not feasible due to the inherent characteristics of the vein visualization devices and the PIVC insertion procedure. Additionally, patient satisfaction scores may have been influenced by the PIVC procedure and individual psychological factors or unrelated clinical practices.

One notable limitation is the imbalance in baseline vascular visibility among groups following tourniquet application; specifically, the transilluminator group had fewer visible veins than the other groups. This discrepancy may have acted as a confounding factor despite randomization, potentially affecting the success rates observed. Consequently, the lower performance observed in the transilluminator group may reflect the device's effectiveness and the disadvantage of poorer initial vascular conditions.

Another limitation is that subgroup analyses were not conducted separately for patients with difficult IV access. Given that both the transilluminator and NIR devices are specifically designed for such cases, the absence of this analysis may limit interpretation regarding their effectiveness in challenging vascular conditions.

Conclusions

In this study, the NIR light and the standard method had higher success rates of PIVC insertion on the first attempt, shortened the procedure time, and increased the satisfaction level of the patients compared to the use of a transilluminator. However, no significant difference was found between the groups in terms of the level of pain and fear of pain experienced by the participants, and it was shown that NIR light and transilluminator methods were not effective in reducing pain. Future studies with larger samples and different populations may support these results and contribute to clinical practice.

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Declarations

Competing interests The authors declare no competing interests.

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