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Correlation between smartphone thermographic temperature and visual infusion phlebitis score in surgical patients with peripheral intravenous access at Dr. Hasan Sadikin General Hospital

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ABSTRACT

Phlebitis is a common complication of peripheral intravenous catheter use that increases patient morbidity and length of hospital stay. The Visual Infusion Phlebitis (VIP) score is widely used for clinical assessment but remains subjective and does not incorporate temperature as an inflammatory marker. Smartphone-based infrared thermography offers a potential objective, non-invasive, and practical adjunct parameter. This study aimed to determine the correlation between local temperature measured by smartphone thermography and VIP score in patients with peripheral intravenous access at Dr. Hasan Sadikin General Hospital. An observational analytic study with a cross-sectional design was conducted in 37 patients with catheter dwell time ≥72 hours. Temperature at the infusion site was measured using a smartphone-based thermal camera and compared with the contralateral healthy area, while phlebitis severity was simultaneously assessed using the VIP score. Data were analyzed using the Shapiro–Wilk normality test and Spearman correlation test at a 95% confidence level. The mean VIP score was 1.86 ± 1.38 (range 0–4), and the mean infusion-site temperature was 35.9 ± 1.7°C (range 33.2–38.1°C). A statistically significant, moderate positive correlation was found between VIP score and thermographic temperature ($r = 0.52$; $p = 0.002$), indicating that higher VIP scores were associated with increased local temperature, reflecting the underlying inflammatory process. These findings suggest that smartphone-based thermographic imaging may serve as a useful objective adjunct in phlebitis evaluation among patients with peripheral intravenous access, complementing rather than replacing comprehensive clinical assessment.

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1. INTRODUCTION

Phlebitis, an inflammation of the superficial veins, is one of the most common complications associated with the use of a peripheral intravenous catheter. Phlebitis may occur together with clot formation (thrombophlebitis), although the exact relationship between phlebitis and thrombus formation is not yet fully understood. This condition can damage the vein so that it can no longer be used for future intravenous access, making the assessment and monitoring of phlebitis important in clinical practice to prevent further complications (Doesburg et al., 2019; Skversky et al., 1964).

Epidemiologically, the incidence of phlebitis associated with peripheral intravenous catheter use remains high in many healthcare facilities. International studies have reported an incidence ranging from 20–40%, depending on the patient population, insertion technique, and catheter dwell time, whereas the standard set by the Infusion Nurses Society (INS) states that the phlebitis rate should be below 5%, a target that is frequently exceeded in practice. In Indonesia, no definitive prevalence figures are available, likely reflecting limited research and publication on intravenous therapy, although available reports suggest that the rate remains high and continues to exceed the INS standard (Fitriyanti, 2014; Gatt et al., 2015; Indarwati et al., 2023).

The factors contributing to phlebitis are multifactorial, including age, comorbid disease, type of infusate, catheter dwell time, insertion site, and catheter care technique (Furlan et al., 2024; Taka et al., 2025; Yasuda et al., 2022). Phlebitis itself is an inflammatory response to endothelial injury that activates inflammatory mediators and causes vasodilation and increased local blood flow, contributing to clinical signs such as pain, redness, and increased local temperature (Chambers et al., 2025; Ji et al., 2025).

In clinical practice, phlebitis is commonly assessed using the Visual Infusion Phlebitis (VIP) score (Chan et al., 2025; Giustivi et al., 2025; Osei-Tutu et al., 2022; Ventura et al., 2021), which classifies the degree of phlebitis based on observable clinical signs ranging from no symptoms to thrombophlebitis (Giustivi et al., 2025; Henedy et al., 2025; Osei-Tutu et al., 2022; Simpson & Zersen, 2023; Ventura et al., 2021). This scale is widely used because it is simple and easy to apply, but it remains subjective because it depends on the examiner's interpretation, and it does not directly incorporate a temperature parameter, even though increased temperature is part of the physiological response to inflammation (Skversky et al., 1964; Wallace et al., 2018).

The relationship between body temperature and disease processes has long been recognized, and skin temperature measurement can serve as an indicator of physiological change. Infrared thermography is an imaging method capable of detecting the distribution of surface temperature non-invasively, and technological advances now allow the use of smartphone-based thermographic devices, such as the FLIR One, which can measure skin temperature easily and without direct contact. Increased local temperature is often associated with the inflammatory process resulting from vasodilation and increased tissue perfusion, so thermographic measurement has the potential to provide additional, non-invasive, rapid, and repeatable information about the tissue surrounding an infusion site (Clark et al., 2003; Wallace et al., 2018).

Infrared thermography has been widely applied in various medical fields, including peripheral perfusion assessment, Raynaud's phenomenon, and other inflammatory conditions (Clark et al., 2003; John et al., 2016). However, a clear research gap remains: while the widely used VIP score is constrained by examiner subjectivity and the absence of direct local temperature measurement, empirical studies evaluating the quantitative correlation between smartphone-based thermographic temperature and phlebitis severity according to the VIP score remain very limited, particularly in Indonesia. To address this gap and determine whether smartphone thermography can serve as an objective diagnostic adjunct, this study aimed to determine the correlation between smartphone thermographic temperature and VIP score in patients with peripheral intravenous access at Dr. Hasan Sadikin General Hospital, Bandung, during the period of January–December 2025. This study is expected to contribute to the development of more objective and non-invasive methods for the early detection of phlebitis. If a significant correlation is found between thermographic temperature and the VIP score, smartphone-based infrared thermography has the potential to be used as an

adjunct to conventional visual assessment, reducing the subjectivity of the VIP score and enabling rapid, repeated, and without direct contact thereby allowing signs of inflammation to be detected earlier before they progress to severe phlebitis.

2. RESEARCH METHOD

This was an analytic observational study with a cross-sectional design conducted in the surgical inpatient ward of Dr. Hasan Sadikin General Hospital, Bandung, from January to December 2025. The main reason for choosing a cross-sectional design is that this design is specifically intended to measure exposure and outcomes simultaneously at a single point in time, making it suitable when the research objective is to determine whether there is a relationship or association between two variables, rather than to establish a cause-and-effect relationship (Baumeister et al., 2026; Pérez-Guerrero et al., 2024). The accessible population consisted of surgical inpatients with a peripheral intravenous catheter. Inclusion criteria were surgical inpatients with peripheral intravenous access, age ≥18 years, and willingness to participate. Exclusion criteria were conditions that could affect temperature distribution (shock, hypothermia, or peripheral perfusion disorders) and severe local infection at the infusion site that could interfere with temperature interpretation.

The minimum sample size was calculated using the sample-size formula for the Pearson correlation coefficient of two numerical variables, assuming an expected correlation coefficient (r) of 0.5 based on prior studies, $Z\alpha/2$ of 1.96 (95% confidence level), and $Z\beta$ of 0.84 (80% power), which yielded a minimum of 29 subjects; after adding 10% to anticipate drop-out, the planned sample size was 33 patients. Subjects were recruited by consecutive sampling until 37 patients were enrolled, exceeding the minimum requirement.

Data were collected from patients whose intravenous catheters had been in place for ≥ 72 hours. This duration threshold was chosen because the incidence of catheter-related phlebitis increases substantially after 48–72 hours of placement, thereby ensuring that a broader spectrum of phlebitis severity (ranging from no inflammation to advanced stages) could be captured for meaningful correlation analysis (Cernuda-Martínez et al., 2025; Cernuda Martínez et al., 2024; Kaplan et al., 2025; Simões et al., 2022). Measurements were taken at a single time point with the patient in the supine position and the extremity exposed. Thermographic imaging was performed using a smartphone-based thermal camera (FLIR One, FLIR Systems), which was specifically selected for its non-invasive, portable, bedside-applicable, and cost-effective nature, as well as its adequate thermal sensitivity for assessing superficial vasculature without causing patient discomfort (Wallace et al., 2018). Thermographic images of the IV insertion site were simultaneously compared with the corresponding healthy anatomical region on the contralateral side, which served as an internal control to account for baseline systemic body temperature, peripheral perfusion, and room temperature fluctuations. Concurrently, the clinical severity of phlebitis was evaluated using the VIP score through clinical inspection and palpation.

Thermographic images were analyzed using ImageJ software to determine the Region of Interest (ROI) at the infusion site and the control area, from which the mean temperature and the temperature difference (ΔT) relative to the contralateral side were derived. The independent variable was skin-surface temperature at the infusion site (°C, interval scale), and the dependent variable was the VIP score, a clinical score from 0 to 5 based on erythema, pain, swelling, induration, and the presence of a palpable venous cord or exudate (ordinal scale). To minimize bias, temperature measurements were performed using standardized procedures, the same device, a trained operator, and a consistent imaging distance and angle, while ambient temperature and humidity were kept relatively constant during data collection.

Data were processed through editing, coding, and entry into IBM SPSS Statistics version 24. Numerical variables were summarized as mean ± standard deviation when normally distributed or as median (minimum–maximum) when not normally distributed, while categorical variables were summarized as frequencies and percentages. The Shapiro–Wilk test was used to assess normality

because the sample size was below 50 (Habibzadeh, 2024; Sharma et al., 2023). Because the VIP score is ordinal and was not normally distributed, the correlation between thermographic temperature and VIP score was analyzed using Spearman's rank correlation test at a 95% confidence level, with $p \leq 0.05$ considered statistically significant.

This study was approved by the Health Research Ethics Committee of Dr. Hasan Sadikin General Hospital, Bandung (approval No. DP.04.03/D.XIII.2.3/665/2026), and was conducted in accordance with the principles of autonomy, beneficence, non-maleficence, and justice, including written informed consent and confidentiality of medical record data.

3. RESULTS AND DISCUSSIONS

Results

A total of 37 patients with peripheral intravenous access met the inclusion criteria and were enrolled in this study. The baseline characteristics of the study population are presented in Table 1. Most participants were female (78.4%), and the mean age was 48.6±17.5 years (range, 18–78 years). The median length of hospital stay was 5 days (range, 3–30 days). The mean VIP score was 1.86±1.38 with a median of 2 (range, 0–4); no patient presented with a VIP score of 5 in this cohort.

Table 1. Characteristics of the study population (n = 37)

Variable	Value
Sex, n (%)	
Male	8 (21.6)
Female	29 (78.4)
Age (years), mean ± SD (range)	48.6 ± 17.5 (18–78)
Length of hospital stay (days), median (range)	5 (3–30)
VIP score, mean ± SD (median)	1.86 ± 1.38 (2)
VIP score category, n (%)	
0	10 (27.0)
1	9 (24.3)
2	8 (21.6)
3	6 (16.2)
4	4 (10.8)

The mean thermographic temperature at the infusion site was 36.0±1.2°C, with a median of 35.9°C (range, 33.7–38.0°C), while the contralateral healthy side ranged from 33.2°C to 36.4°C with a mean of approximately 35.0°C. The mean temperature difference (ΔT) between the infusion site and the contralateral side was 0.1±1.1°C (range, –1.1°C to 3.2°C). As shown in Table 2, both the ROI area and the temperature range at the infusion site tended to increase progressively with higher VIP scores.

Table 2. Correlation between VIP score, ROI area, and thermographic temperature range

VIP Score	ROI Area (pixels)	Temperature Range (°C)
0	7200	33.7–35.5
1	10500	35.0–36.2
2	14800	36.0–37.0
3	18900	37.0–37.8
4	22500	37.5–38.0

The Shapiro–Wilk normality test (Table 3) showed that age ($p = 0.182$) and thermographic temperature ($p = 0.418$) were normally distributed, whereas VIP score ($p = 0.001$) and length of hospital stay ($p = 0.008$) were not normally distributed. Because the VIP score, one of the two main study variables, was not normally distributed and was measured on an ordinal scale, the correlation between thermographic temperature and VIP score was analyzed using Spearman's rank correlation test.

Table 3. Shapiro–wilk normality test results

Variable	Statistic	p-value	Interpretation
Age	0.096	0.182	Normal
VIP score	0.872	0.001*	Not normal
Temperature	0.971	0.418	Normal
Length of stay	0.889	0.008*	Not normal

Spearman's rank correlation analysis revealed a statistically significant moderate positive correlation between VIP scores and thermographic temperature (n = 37; r = 0.52; p = 0.002), indicating that higher VIP scores are consistently accompanied by higher thermographic temperatures at the infusion insertion site. From the perspective of monitoring in the care unit, these empirical results have two main implications: first, the detected temperature increase even at low VIP scores (35.0–36.2°C at VIP 1 vs. 33.7–35.5°C at VIP 0) suggests that smartphone thermography can facilitate the early detection of subclinical localized hyperthermia before clear physical signs appear. Second, the progressive expansion of the thermal region of interest (ROI) area (from 7.200 pixels at VIP 0 to 22.500 pixels at VIP 4) provides a practical quantitative metric for routine bedside monitoring to track the spatial spread of vascular inflammation along the cannulated vein over time.

Discussion

This study demonstrated a statistically significant positive correlation of moderate strength between VIP score and skin-surface temperature measured by smartphone thermography (r = 0.52; p = 0.002). This finding indicates that an increase in the degree of local inflammation, represented by the VIP score, is associated with an increase in skin-surface temperature. Physiologically, this can be explained by the inflammatory mechanism that causes vasodilation and increased tissue perfusion, thereby increasing the heat emission that can be captured by a thermal camera (Doesburg et al., 2019; Gatt et al., 2015).

This result is consistent with the study by Doesburg et al., which showed that infrared thermography can objectively and non-invasively detect temperature changes in superficial inflammatory processes such as phlebitis, and with the study by Gatt et al., which showed that variations in skin temperature reflect changes in microcirculation occurring in certain pathological conditions (Doesburg et al., 2019; Gatt et al., 2015).

Statistically, a correlation coefficient of r = 0.52 indicates a moderate-strength relationship, suggesting that although local skin surface temperature reflects inflammatory vasodilation, it is not entirely determined by the VIP score (Doesburg et al., 2019; Kesztyüs et al., 2023). From a clinical perspective, this moderate correlation is highly significant: it confirms that smartphone thermography and the VIP score assess complementary dimensions of phlebitis (Ray-Barruel et al., 2014; Wallace et al., 2018). While the VIP score relies on a composite clinical assessment which combines subjective symptoms (such as pain) and physical findings (such as induration or palpable venous cords) thermography offers a purely objective quantitative measurement of local microvascular thermal emissions (Doesburg et al., 2019; Skversky et al., 1964). This moderate correlation suggests that thermodynamic changes may precede visual changes in the skin, thereby enabling the detection of subclinical microvascular hyperemia in the early stages before clear clinical signs appear (Gatt et al., 2015; Wallace et al., 2018). Conversely, local temperature can also be influenced by non-inflammatory variables, such as systemic perfusion, room temperature, infusion fluid temperature, and subcutaneous tissue thickness (John et al., 2016; Kesztyüs et al., 2023). Therefore, clinically, smartphone thermography should not be viewed as a standalone substitute for VIP score assessment, but rather as a non-invasive, objective diagnostic adjunct that enhances clinical vigilance, particularly when physical signs are still subtle or in the earliest stages (Ray-Barruel et al., 2014; Wallace et al., 2018).

From a clinical perspective, an increase in temperature at the intravenous catheter insertion site is one manifestation of the inflammatory process. In phlebitis, inflammation leads to the release of mediators such as prostaglandins and cytokines that trigger vasodilation and increased vascular

permeability, resulting in increased local blood flow and elevated skin-surface temperature (Gahlot et al., 2014; Ray-Barruel et al., 2014). Nevertheless, the moderate strength of the correlation (r = 0.52) indicates that the VIP score, as a clinical parameter, does not always change linearly with temperature, which may be explained by the difference between subjective clinical assessment and objective temperature measurement, as well as external factors such as room temperature, humidity, camera distance and angle, and patient acclimatization before examination.

Table 2 shows that the area of the *Region of Interest* (ROI) and the temperature range increase progressively as the VIP score rises. At lower VIP scores (0–1), the thermal signal elevation remains localized around the puncture site (7.200–10.500 pixels). Conversely, at higher VIP scores (3–4), the thermal ROI area expands significantly (reaching up to 22.500 pixels) in tandem with an increase in peak local temperature (37.5–38.0°C). From a pathophysiological perspective, this expansion of the thermal ROI area reflects the spatial propagation of endothelial injury as well as mediator-driven vasodilation extending along the venous vessel axis (Gahlot et al., 2014; Ji et al., 2025). As the activity of the inflammatory cascade increases, increased vascular permeability and hyperperfusion extend beyond the initial catheter insertion site (Ji et al., 2025; Ray-Barruel et al., 2014). Clinically, this spatial thermal mapping provides a crucial picture of the extent of vascular anatomical involvement (Doesburg et al., 2019). While conventional visual inspection primarily assesses localized superficial erythema, the expansion of the region of interest (ROI) measured quantitatively by thermography is able to capture the longitudinal progression of inflammation along the cannulated vein, thereby serving as a valuable marker for detecting spreading or ascending phlebitis before it progresses to extensive thrombophlebitis (Doesburg et al., 2019; Ray-Barruel et al., 2014).

The use of thermography in this context adds value as an objective parameter that complements the subjective VIP score. In addition to detecting temperature change quantitatively, thermography also enables an evaluation of inflammatory progression, and smartphone-based thermography specifically offers the advantages of accessibility, non-invasiveness, speed, and bedside applicability (Wallace et al., 2018).

Data collection in this study was performed in patients with a catheter dwell time of ≥72 hours, since the incidence of phlebitis is known to increase after 48–72 hours of peripheral catheter placement; this time point was chosen so that the VIP score distribution obtained would more representatively reflect the clinical condition that develops during intravenous therapy (Simões et al., 2022; Urbanetto et al., 2016).

No patient with a VIP score of 5 was found in this study. This indicates that most phlebitis cases in the study population fell within the spectrum from no phlebitis to severe phlebitis, but did not reach the most severe grade, which is usually accompanied by advanced clinical signs such as overt venous thrombosis. The absence of VIP score 5 cases may reflect earlier clinical detection and intervention, such that the catheter was removed or managed before reaching the maximum grade (Gallant & Schultz, 2006; Tzolos & Salawu, 2014), and it also means that the correlation obtained in this study more specifically represents the relationship between thermographic temperature and VIP scores 0 through 4.

This study has several limitations. The relatively small sample size (n = 37) and single-center design may limit the generalizability of the findings. Variation in environmental conditions during temperature measurement may also introduce bias, and the subjective nature of VIP scoring is susceptible to inter-observer variation. The absence of VIP score 5 cases means the data do not cover the entire spectrum of phlebitis severity. Future studies with larger, multicenter samples, stricter environmental control, and a more complete VIP score distribution are therefore needed to strengthen the validity of these findings.

Overall, this study shows that there is a significant relationship between VIP score and skin-surface temperature. These findings support the use of thermography as an objective adjunct in the assessment of phlebitis, although it still needs to be combined with clinical evaluation to improve diagnostic accuracy.

4. CONCLUSION

There is a statistically significant moderate positive correlation between smartphone thermographic temperature and the Visual Infusion Phlebitis (VIP) score in patients with peripheral intravenous access at Dr. Hasan Sadikin General Hospital. An increase in the VIP score, which reflects the degree of clinical inflammation, tends to be accompanied by an increase in local temperature at the infusion insertion site, as well as an expansion of the area of thermal changes (Region of Interest/ROI). This indicates that temperature changes in phlebitis not only increase in terms of heat intensity but also expand in spatial distribution along the vascular pathway.

The primary contribution of smartphone-based thermographic imaging lies in its ability to provide objective information regarding skin surface temperature and the extent of inflammatory spread in a non-invasive, rapid, and bedside-applicable manner. The implication for the development of phlebitis monitoring procedures in hospitals is that smartphone thermography can be considered as an additional objective parameter to complement conventional, subjective clinical assessments (VIP score), thereby improving the accuracy of monitoring phlebitis progression. Given that the results obtained are correlative in nature, the use of thermography in monitoring procedures must still be interpreted with caution and combined with a comprehensive clinical assessment.

To improve the validity and clinical utility of smartphone thermography in future studies, several key directions are recommended: first, conducting a prospective, multicenter study with a larger sample size to improve the generalizability of the findings; second, ensuring the inclusion of the full spectrum of phlebitis severity, particularly severe cases with a VIP score of 5; third, implementing stricter environmental controls such as standardizing room temperature and humidity, imaging distance and angle, and patient acclimatization periods to minimize measurement bias; and fourth, exploring longitudinal study designs to continuously monitor temperature dynamics throughout the duration of catheter placement. Therefore, smartphone-based thermographic imaging can provide objective information regarding skin surface temperature related to the degree of clinical inflammation as reflected by the VIP score, and may be considered as an additional parameter to complement clinical assessment. Since the results obtained are correlational, they must be interpreted with caution and combined with comprehensive clinical judgment. To enhance the validity and clinical utility of smartphone thermography in future research, several research directions are recommended: first, conducting a prospective, multicenter study with a larger sample size to improve the generalizability of the findings; second, ensuring the complete inclusion of the full spectrum of phlebitis severity, particularly cases with a VIP score of 5; third, implementing stricter environmental controls (such as standardizing room temperature, humidity, imaging distance and angle, and patient acclimatization periods) to minimize thermal measurement bias; and fourth, exploring longitudinal study designs to dynamically monitor thermal changes over the duration of catheter placement.

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