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A REVIEW OF THE USE OF INFRARED THERMOGRAPHY IN THE EARLY DETECTION OF PHLEBITIS

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Abstract: *Background: The first use of thermography was discovered in 1957 when researchers found that the temperature of the skin over breast cancer was higher than the normal tissues. In a hospital setting, a peripheral intravenous catheter (PIVC) is the most frequently performed procedure, and approximately 33-67% of admitted patients require at least one peripheral vein insertion. Moreover, the manifestation of phlebitis includes local changes in skin temperatures, due to the occurrence of an inflammatory process because of body response. Objectives: The study aimed to examine the literature and integrate the body and PIVC insertion site temperatures and the Visual Infusion Phlebitis (VIP) score of phlebitis among adult patients with PIVCs. Methods: The search strategy began with six electronic databases (e.g. CINAHL and Medline). Considering the inclusion criteria, published studies that examined the use of infrared thermography in the early detection of phlebitis among adult patients with PIVC in the timeframe of 2011 through 2021 were chosen. Data extraction and analysis were completed on all included studies. The final sample for this review comprised 7 studies. Findings: Based on common meanings and central issues, this signifies that IFT may contribute as a diagnostic tool to detect early manifestation of phlebitis due to the direct proportion of IFT results and the VIP scoring system. Conclusion: In general, the categories that emerged in this study could be useful in extending the understanding of the field of infrared thermography in detecting the development of phlebitis.*

Keywords: *Phlebitis; infrared thermography; Peripheral Intravenous Catheter; Visual Infusion Phlebitis*

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Introduction

In recent decades, infrared thermography (IFT) has been a non-invasive, cost-effective imaging technique and has increasingly been integrated into clinical medicine (Stanley et al., 2024). IFT relies on detecting thermal radiation emitted from specific areas using a thermographic camera, which enables the visualization of heat distribution on the surface and allows for the measurement of peripheral temperatures (Stanley et al., 2024). As a non-invasive technique for monitoring changes in peripheral body temperature, IFT holds significant promise as a diagnostic tool for the early detection of complications related to peripheral intravenous catheters (PIVCs), particularly phlebitis (Shaydakov et al., 2017). Hence, the introduction of IFT into the medical field has a high potential to be one of the diagnostic tools for the early detection of PIVC complications, particularly phlebitis incidence.

In hospital settings, peripheral intravenous catheter (PIVC) insertion is one of the most commonly performed procedures, with approximately 33-67% of admitted patients requiring at least one PIVC placement (Lulie et al., 2021). Factors in selecting an appropriate PIVC include estimating the expected duration of use and the type of treatment, typically intravenous therapy (Guanche-Sicilia, 2021). PIVCs are crucial for administering intravenous medications, obtaining blood samples for diagnostic tests, and providing parenteral nutrition (Lulie et al., 2021). Despite their advantages, PIVC insertions can lead to complications such as extravasation, hematoma, infection, and phlebitis (Pasalioglu et al., 2014). Among these, phlebitis is the most common complication (Kaphan et al., 2024). Phlebitis is an acute inflammation of the blood vessel walls, often caused by mechanical irritation or chemical reactions, which affects the venous endothelium in the catheterized area (Mandal et al., 2019; Sicilia, 2021). Clinically, phlebitis is characterized by symptoms such as swelling, pain, discomfort, redness around the catheter site, and a palpable cord-like sensation along the vein (Tertuliano et al., 2014). The introduction of the Visual Infusion Phlebitis (VIP) score as a tool for early phlebitis detection has proven effective in prompting the removal of problematic catheters and has successfully reduced phlebitis rates to below the 5% threshold recommended by the Infusion Nurses Society (INS) (Tzolos & Salawi, 2014). Achieving these results relies on strict adherence to cannulation guidelines and consistent use of the VIP score for assessment and documentation (Tzolos & Salawi, 2014).

Phlebitis manifests through localized changes in skin temperature due to the inflammatory response triggered by the body's reaction (Macklin et al., 2003). Additionally, the type of medication administered through peripheral access and the duration of catheter dwell time are directly related to the incidence of phlebitis (Abolfotouh et al., 2014). In one study, the rate of phlebitis was found to be 17.6%, exceeding the recommended rate of 3% and highlighting that 39.3% of patients with PIVCs experienced one or more complications (Abolfotouh et al., 2014). Another study by Daud & Mohamad (2021) reported a high incidence of phlebitis at 36.1% among 321 patients. Ray-Barruel et al. (2014) identified seventy-one different phlebitis assessment scales, with some authors adapting existing tools such as the VIP score or developing their scales. The authors added that the lack of standardization in these assessment tools, complicates the comparison of results, as 56% of the reviewed studies used various phlebitis assessment scales.

Given these considerations, it is crucial to evaluate the feasibility of infrared thermography (IFT) as a diagnostic tool for early detection of phlebitis. Advances in technology suggest a promising future for integrating IFT into medical practice. However, the limited number of relevant studies on the relationship between IFT and phlebitis hampers information gathering.

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As a new methodology in healthcare, IFT's effectiveness and applicability as a diagnostic tool require further investigation. Therefore, this review aims to analyze the literature on body and PIVC insertion site temperatures and the VIP score for phlebitis among adult patients with PIVCs.

Materials and Methods

Relevant empirical literature was identified from searches of computerised databases. A search of the CINAHL, Scopus, Web of Science, and PubMed databases was conducted using the following criteria: English-language text published between 2013 and 2023. The search terms were infrared thermography "OR" infrared combined with "AND" phlebitis "OR" phlebitis score "AND" peripheral intravenous catheter "OR" intravenous catheter. Dissertations and theses were excluded from the search strategy. The inclusion criteria were as follows: (a) peer-reviewed articles written in the English language published in the past 20 years (from January 2003 through December 2012) and (b) empirical studies that focused on the use of infrared thermography. The articles were selected through title and abstract screening from "Infrared thermography in peripheral intravenous catheter"-related articles among internationally published studies. A secondary abstract review was performed on the initially screened articles, with a review of the full text. The search strategy yielded 379 articles. After eliminating 173 duplicates, we reviewed all titles for possible inclusion and identified 274 articles. Two hundred and fifty-one (251) were excluded for one or more of the following reasons: (a) main focus on infrared thermography and other majors; (b) main focus on breast cancer risk assessment and prognosis; (c) main focus on using infrared thermography in burn trauma; (d) main focus on medical diagnosis; and (e) main focus on guiding to the use of infrared thermography. Of the 23 original empirical studies from the review of literature, 16 articles were excluded because infrared thermography was used with other vascular diseases such as deep vein thrombosis (DVT), and areas involving angiogenesis. This resulted in 7 articles being included in this review.

Results

Of the 7 studies included in this review, six studies indicate that IFT may serve as a valuable diagnostic tool for the early detection of phlebitis, due to its direct correlation with the Visual Infusion Phlebitis (VIP) scoring system. These studies highlight that IFT can be effective in identifying early manifestations of phlebitis, as there is a proportional relationship between the results obtained from IFT and the VIP score. The research reviewed has focused on four key aspects of infrared thermography as a diagnostic tool for detecting early symptoms of phlebitis: (a) thermoregulation, which refers to the ability of IFT to accurately measure temperature changes associated with inflammatory responses; (b) high accuracy, highlighting the precision with which IFT can detect variations in skin temperature that may indicate the onset of phlebitis; (c) patient preparation, emphasizing the importance of properly preparing patients to ensure accurate thermographic measurements; and (d) ease of use, which points to the user-friendly nature of IFT and its practical application in clinical settings. These factors collectively support the potential of IFT to enhance early detection and management of phlebitis, improving patient outcomes and reducing the incidence of complications associated with peripheral intravenous catheters.

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Discussion
The ability of IFT to accurately measure temperature changes associated with inflammatory responses.

The concept of utilizing infrared thermography (IFT) for the early detection of phlebitis has been explored for several decades. However, in the early years of thermography's development, there were relatively few studies investigating its application in detecting intravascular diseases (Ammer, 2008). Over the past ten years, advancements in infrared technology have significantly enhanced the ability to objectively analyze digital radiographic data for various medical applications. Consequently, there has been a growing emphasis on standardizing thermographic techniques to improve their clinical utility.

A study by Doesburg et al. (2019) utilized an infrared camera to measure the temperature difference (ΔT) between a reference point and the site of peripheral catheter insertion. The results revealed that IFT temperature measurements were notably higher in patients with a VIP score of ≥1 compared to those with a VIP score of 0. This study found that the ΔT between the insertion site and the proximal reference point was significantly correlated with the VIP score, indicating a clear association between thermographic measurements and the severity of phlebitis. The study concluded that IFT could be an effective diagnostic tool for detecting the early manifestations of phlebitis, as its results show a direct proportionality with the VIP scoring system. The authors noted that despite the use of more precise measurement techniques in the validation study, the significant ΔT values observed highlight the potential of IFT in clinical settings. The Visual Infusion Phlebitis (VIP) score, which ranges from level 0 (no phlebitis) to level 5 (thrombophlebitis), was used to assess the severity of phlebitis, providing a comprehensive framework for evaluating the condition.

Factors influence

Thermoregulation
Thermoregulation is a crucial aspect of homeostasis, with the average normal body temperature typically around 37°C. It involves the body's mechanism for maintaining optimal temperature through tightly regulated self-regulation, independent of external temperature variations (Shaydakov et al., 2017). However, it is recognized that different body parts exhibit variable temperatures due to various internal and external factors (Osilla et al., 2021). For instance, the temperature of the most distal parts of the lower extremities is generally lower, ranging from 2°C to 6°C below the average body temperature (Shaydakov et al., 2017). Conversely, the head and neck regions are typically the warmest, followed by the trunk, with temperatures decreasing progressively toward the limbs and acral regions (Szentkuti et al., 2011).

An elevation in temperature often accompanies signs of inflammation, such as pain and redness (Doesburg et al., 2019). Inflammation serves as an adaptive response mechanism aimed at restoring homeostasis and facilitating survival during infection or injury (Medzhitov, 2010). The association between inflammation and warmth is well-documented, as phlebitis involves the injury or irritation of the interior wall of a vein (the tunica intima), which consists of a single layer of tightly packed endothelial cells. This irritation leads to inflammation due to the body's response, resulting in the release of histamine, bradykinin, and serotonin. These mediators initiate pain responses by stimulating prostaglandin synthesis and cause vasodilation, thereby increasing blood flow to the affected area (Macklin et al., 2003).

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Increased capillary permeability allows fluids and proteins to leak into the interstitial space, leading to oedema and tenderness (Macklin et al., 2003). The activation of the platelet clotting cascade by procoagulant factors in the endothelial lining, combined with the release of pyrogens at the injury site, stimulates the hypothalamus and raises local body temperature (Macklin et al., 2003). Phlebitis results from the irritation of the venous endothelium in the catheterized segment, with common manifestations including localized warmth, swelling, and redness (Sicilia et al., 2021). The use of rating scales such as the Visual Infusion Phlebitis (VIP) scale, the Phlebitis scale, and the Maddox scale helps in assessing the severity of phlebitis. Since the VIP score includes erythema or inflammation in all grades, the correlation between inflammation, local vasodilation, and enhanced metabolism could potentially be detected by IFT (Sicilia et al., 2021).

Moreover, the linear relationship between blood flow and skin surface temperature is highlighted by the heat transfer from arterioles to the dermis, through the epidermis, and to the surroundings (Huang et al., 2011). This suggests that IFT could be particularly useful in vascular diseases, as the temperature of extremities is largely influenced by peripheral blood flow (Huang et al., 2011). Bagavathiappan et al. (2009) noted that IFT was first documented as a research method for early preclinical diagnosis of breast cancer in 1956. Since then, IFT has been recommended for improving the diagnosis of various medical conditions related to local temperature changes, providing quantifiable thermal images (Bagavathiappan et al., 2009). These changes are influenced by ambient factors as well as natural processes such as conduction, convection, infrared radiation, and evaporation from the skin surface (Szentkuti et al., 2011).

While IFT is useful for assessing vascular diseases, reports have shown no significant differences in rest temperatures between patients with peripheral artery disease (PAD) and healthy individuals (Huang et al., 2011). Temperature gradients are observed in patients with vascular disorders and ischemic gangrene, where affected regions are 0.7°C to 1°C warmer than normal regions due to slow blood circulation (Bagavathiappan et al., 2009). Environmental temperature also affects body surface temperature, as vasoconstriction and vasodilation regulate heat radiation when environmental temperatures are neutral (Hibino et al., 2003). Although phlebitis is primarily characterized by warmth, swelling, and redness, the VIP scale stages 1 to 4 do not include warmth as a criterion, with only stage 5 encompassing severe pain, a palpable venous cord, and fever (Ray-Barruel et al., 2014). This limitation may hinder the ability of infrared thermometers to detect the early development of phlebitis. Therefore, it is essential to thoroughly revise and discuss the study's objectives to address these challenges and optimize the use of IFT for early phlebitis detection.

Achieve High Accuracy

It is commonly believed that skin temperature should remain relatively constant over time and be symmetrical on both sides of the body. However, various factors can affect skin temperature fluctuations, which can challenge the feasibility of infrared thermography (IFT) in detecting the early symptoms of phlebitis (Fernández-Cuevas et al., 2015). To address these challenges, proper patient preparation is crucial. Patients need to adhere to specific rules and restrictions to prevent alterations in their skin temperature, ensuring the accuracy and reliability of thermographic measurements.

Preparation for the procedure involves several critical steps to create a controlled environment. Initially, patients should rest in a room with minimal disturbance and a controlled environment where both temperature and humidity are maintained at equilibrium to achieve stable body temperature (Fernández-Cuevas et al., 2015). Additionally, sources of air convection should be kept away from the patient to reduce variables that might affect temperature measurements (Bagavathiappan et al., 2009).

Patients are also advised to avoid excessive sun exposure for at least two days before the procedure and to refrain from consuming food, liquids, and medications for at least two hours before the examination. This helps in stabilizing skin temperature and obtaining more accurate results (Szentkuti et al., 2011). Some studies recommend that patients remain still and avoid touching the area to be examined for at least 10 minutes before the procedure to allow skin temperature to stabilize (Faria et al., 2012).

Moreover, Ludwig et al. (2014) emphasized the importance of patient orientation and adherence to guidelines before undergoing thermographic procedures. Recommendations include avoiding alcohol for 24 hours before the procedure, refraining from coffee and cigarettes at least two hours before the examination, and avoiding vigorous physical activities on the day of the test. These measures help in maintaining a stable skin temperature and minimize fluctuations.

Considering that skin temperature is a physical quantity reflecting thermal energy transfer between objects of different temperatures (Ludwig et al., 2014), standardizing the technique and protocol for the procedure is essential. Consistent adherence to these preparatory steps and protocols can enhance the sensitivity and reliability of IFT outcomes, ensuring more accurate detection of early phlebitis symptoms.

IFT Feasibility

A study conducted on 21 patients in an oncology ward aimed to enhance and increase the frequency of Visual Infusion Phlebitis (VIP) scoring as an assessment tool for early signs of phlebitis (Tzolos et al., 2014). This study employed a modified version of the original Maddox scale, the VIP scale, designed to numerically rate the incidence of phlebitis based on observable symptoms (Tzolos et al., 2014). Similarly, Lulie et al. (2021) investigated the incidence and potential factors associated with peripheral vein phlebitis among hospitalized patients using Jackson’s Visual Infusion Phlebitis Scoring System. Their findings revealed that the overall incidence of phlebitis was 70%. Among these cases, 51% were classified as Grade 3, and 33% as Grade 4. Advanced stage thrombophlebitis (Grade 5) occurred in only 1.5% of cases. These findings indicate that the incidence of phlebitis was significantly higher than the acceptable rate of 5% recommended by the Infusion Nurses Society (Gorski et al., 2021). Specifically, the incidence of phlebitis for VIP score grades 1 and 2 were 12.7% and 1.9%, respectively (Lulie et al., 2021). The lower incidence rates of Grades 1 and 2 might be attributed to the minimal presentation of criteria observed during the study period, as the characteristics of Grades 1 and 2 in the VIP scoring system are similar, making it challenging to differentiate the symptoms at the catheter insertion site.

In a separate study, Lee et al. (2019) utilized a modified INS scale and reported a phlebitis incidence rate of 35.9%, including patients with Grade 0, who experienced pain at the insertion site but no observable clinical symptoms. Despite the use of various phlebitis assessment scales in previous studies, both scales incorporate both objective clinical signs and subjective symptoms reported by patients (Lee et al., 2019). When comparing the INS and VIP assessment scales, the VIP scale was noted for achieving an acceptable reliability correlation of ≥ 0.85,

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where a correlation coefficient closer to 1 indicates greater reliability (Ray-Barruel et al., 2014). In contrast, the most recent version of the INS assessment scale exhibited questionable reliability, though some research nurses provided valuable feedback indicating that the INS phlebitis scale was effective for identifying and measuring phlebitis and was easy to apply clinically (Ray-Barruel et al., 2014).

The study by Lulie et al. (2021) also highlighted that among the sample population, 110 patients developed phlebitis between days 7 and 14 of hospitalization, marking the highest incidence compared to only 19 patients who developed phlebitis within the first 3 days of admission. This finding suggests a strong association between the duration of hospital stay and the likelihood of developing phlebitis. Furthermore, the catheter dwell time was identified as another significant factor contributing to phlebitis risk. It was observed that phlebitis occurred more frequently in patients with catheter dwell times exceeding 96 hours compared to those with catheters in place for less than 72 hours. This finding is consistent with other studies and underscores the recommendation by the CDC to replace indwelling catheters every 72 to 96 hours to mitigate the risk of phlebitis (O'Grady et al., 2011). Effective monitoring of complications is crucial, and nurses must make informed decisions, such as removing the PIVC before the end of the intended period, to prevent the development of advanced-stage phlebitis, which may indicate inadequate catheter management practices (Lulie et al., 2021).

Patient Preparation

Proper patient preparation and a carefully controlled environment are crucial for obtaining reliable and accurate results with infrared thermography. The preparation of patients before performing the procedure is essential to ensure that temperature readings are not influenced by external factors. This preparation involves maintaining a carefully regulated environment in terms of ambient temperature, humidity, and ventilation (Faria et al., 2012).

Patients should be allowed to rest in a room with a controlled number of people, where both the room temperature and humidity are carefully regulated to achieve an equilibrium body temperature (Faria et al., 2012). Additionally, air convection sources should be kept away from the patient to minimize variables that could affect temperature measurements (Bagavathiappan et al., 2009). To ensure accurate results, patients should avoid excessive sun exposure for at least two days before the procedure. Furthermore, they should refrain from consuming food, liquids, and medications for at least two hours before the examination (Szentkuti et al., 2011). Some studies also suggest that patients should remain undisturbed and avoid touching the area to be examined for at least 10 minutes before the procedure to stabilize skin temperature (Faria et al., 2012).

According to Hibino et al. (2003), proper preparation and patient orientation are key to maintaining consistent temperature readings. This includes avoiding alcohol for 24 hours before the procedure, restricting coffee and cigarette consumption at least two hours prior, and abstaining from vigorous physical activity on the day of the examination. Temperature is a physical quantity representing thermal energy, which can be transferred when a thermal object comes into contact with another object that is either hotter or colder (Hibino et al., 2003). Therefore, standardizing the technique and protocols throughout the procedure, including the timing of measurements, is essential for achieving higher sensitivity and reliability of the outcomes.

Conclusion

IFT uses thermal imaging systems that detect the temperature changes on surfaces, phlebitis or thrombophlebitis clinical manifestations also include warmth near the cannulation region (Lulie et al., 2021). The categories that emerged in this review study could be useful to extend the understanding of the field of infrared thermography in detecting the development of phlebitis. This review study showed that infrared thermography may be a promising and helpful technique to objectively identify the early development of phlebitis. An increased ΔT appears to be a risk factor for phlebitis. This further concludes that IFT may have potential in diagnosing patients with phlebitis.

In conclusion, the successful application of infrared thermography (IFT) for the early detection of phlebitis relies heavily on meticulous patient preparation and a controlled testing environment. Proper preparation, including managing ambient conditions and patient adherence to pre-procedure guidelines, is essential for obtaining accurate and reliable temperature measurements. By minimizing external influences and ensuring that patients follow specific restrictions, the potential for detecting subtle thermal changes associated with phlebitis is greatly enhanced. Although IFT shows promise as a diagnostic tool, the effectiveness of this technology depends on standardizing procedures and protocols to ensure consistent results. Future research should focus on refining these methods and exploring the full potential of IFT in clinical settings. Addressing the current limitations and further validating the technique could significantly improve the early diagnosis of phlebitis and enhance patient care. As the technology evolves, ongoing efforts to integrate IFT into routine clinical practice will be crucial for advancing the accuracy of diagnostic assessments and ultimately improving patient outcomes in the management of peripheral intravenous catheter complications.

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Conflict of Interest

The authors declare that they have no competing interests.

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