Original article

Thermographic analysis in the evaluation of venous leg ulcers

Análise termográfica na avaliação de úlceras venosas de pernas

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ABSTRACT | OBJECTIVE: To analyze the temperature of the venous ulcer in comparison to the temperature of the healthy contralateral limb and whether this heat emission is associated with the severity of the injury. **METHODS:** Analytical cross-sectional study conducted in a private institution in Salvador/Bahia from March to August 2021. Sociodemographic data were collected, as well as a clinical evaluation of the 33 participants and the 66 lower limbs, thermographic image capture of venous ulcer, and thermal analysis. **RESULTS:** The mean age of the 33 participants was 70 ± 12.49 years, the race/color, self-declared, brown (14; 42.4%), male (17; 51.5%). They reported alcoholism (10; 30.3%). Regarding the correlation between the maximum and mean temperature of the limb with venous ulcer versus the contralateral limb, it showed a correlation (p=0.001) in all regions evaluated. Regarding alcoholism, it was correlated with the maximum temperature of the ulcer (p=0.003), border (p=0.015), and center (p=0.006). Regarding the PUSH ≥12, it was correlated with geographic morphology (p=0.001) and poorly defined (p=0.008). Delta correlated with recurrence (p=0.004) and Severe Delta with ulcer time >12 months (p=0.024), recurrence, and alcoholism (p=0.038). **CONCLUSIONS:** Thermography in the evaluation of venous ulcers in the lower limbs contributes to the thermal monitoring of inflammatory processes and tissue perfusion.

KEYWORDS: Varicose Ulcer. Thermography. Nurses. Injuries. Lower Limbs.

RESUMO | OBJETIVO: Analisar a temperatura da úlcera venosa em comparação à temperatura do membro contralateral sadio e se esta emissão de calor tem associação com a gravidade da lesão. **MÉTODOS:** Estudo transversal analítico realizado em uma instituição privada em Salvador/Bahia, de março a agosto de 2021. Foram coletados dados sociodemográficos, avaliação clínica dos 33 participantes e dos 66 membros inferiores, captação da imagem termográfica da úlcera venosa e análise térmica. **RESULTADOS:** A média de idade dos 33 participantes era de 70 ± 12,5 anos, a raça/cor, autodeclarada, parda (14; 42,4%), sexo masculino (17; 51,5%). Referiam etilismo (10; 30,3%). Quanto à avaliação entre a temperatura máxima e média do membro com úlcera venosa *versus* o membro contralateral, apresentou correlação (p=0,001) em todas as regiões avaliadas. Em relação a etilismo apresentou correlação com a temperatura máxima da úlcera (p=0,003), borda (p=0,015) e centro (p=0,006). No que diz respeito ao PUSH ≥12, apresentou correlação com a morfologia geográfica (p=0,001) e mal delimitada (p=0,008). O Delta apresentou correlação com recidiva (p=0,004) e Delta Grave com o tempo de úlcera >12 meses (p=0,024), recidiva e etilismo (p=0,038). **CONCLUSÕES:** A termografia na avaliação da úlcera venosa em membros inferiores contribui no monitoramento térmico de processos inflamatórios e da perfusão tecidual.

PALAVRAS-CHAVE: Úlcera Venosa. Termografia. Enfermeiras e Enfermeiros. Lesões. Membros Inferiores.

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Introduction

Chronic lower limb ulcers, with high morbidity and negative impacts on quality of life, constitute a public health problem.[1-4] Venous ulcer (VU) is conceptualized by the discontinuity of the skin barrier that reaches the dermis, lasting more than six weeks and with frequent recurrences. It can be caused by venous insufficiency, arterial disease, diabetic neuropathy, vasculitis, or hematological diseases.[1,5]

The prevalence of VU in the general population ranges from 1% to 3%, and this percentage increases when the age is greater than 65 years.[1,5-9] In relation to the Brazilian population, epidemiological records are scarce, but it is estimated that the occurrence of individuals with venous ulcers reaches the range of 3%.[10-12] Oliveira, Soares, and Pires[13] show in their study in the city of Vitória da Conquista, Bahia, that the prevalence of venous ulcers reaches 83.3%.

These lesions commonly affect the lower and distal third of the legs, usually in the malleolar region.[6,14] UVs are responsible for about 70% to 90% of ulcers in the lower limbs.[5-6,12] The normal healing process of a skin lesion is dynamic and complex[1,11]; it takes, on average, four weeks to reduce the size of the wound by 50%.[15]

The diagnosis is performed by clinical evaluation, physical examination, imaging tests, and laboratory tests. Among the instruments used to assess the injuries is the one chosen by the service where the research took place, the Pressure Ulcer Scale for Healing (PUSH), developed to evaluate the evolution of wound healing[16] with a scale ranging from 0 to 17, the result of the sum of the evaluation of the three parameters and their subscores: area, amount of exudate and appearance of the ulcer bed in the healing process. The lowest scores indicate better condition and the highest ones show worse ulcer conditions.[17]

Thermography or Infrared Thermography (IRT) is a complementary method of evaluation of VU, non-contact and non-invasive that, through a camera, detects the emission of heat from the surface of the human body. Therefore, it can perceive normal or abnormal vascular functioning in skin lesions.[18,19]

The images emitted by the thermographic equipment show minimal temperature differences that may be related to pathological processes.[19] When the thermographic analysis detects an increase in local heat, it means it may be associated with inflammatory processes or infection. When low temperatures are present, these may be related to a slow healing process resulting from a decrease in oxygen in the affected area.[15]

A recent study demonstrates that thermography is able to identify pathological changes and the probability of venous ulcers.[20] It also shows the value of thermography in the objective evaluation of inflammatory and infectious processes in chronic ulcers.[6,19-21] There are studies designed to evaluate thermography, comparing it with clinical characteristics.[22-27] The inflammatory process is usually evaluated by the signs of redness, heat, edema, and exudate, all subjective to the examiner's analysis. In this way, thermography can be used as an efficient tool, which contributes to the evaluations performed by stomatherapeutic nurses and dermatological nurses, in order to favor the therapeutic conduct.

The conventional evaluation of the venous ulcer, by a professional nurse, consists of detailed history and physical examination.[20] This includes visual analysis and perception of tissues, their conditions[28], and the type of treatment to be applied. The study by O'Meara et al.[29], a systematic review of all randomized controlled trials, involving more than 4,000 participants, showed the role of the nurse in the management of venous ulcers and the effects on healing, when determining the use of bandages and compression stockings.

Thus, the specialist nurse, holder of scientific knowledge and technical skills, is responsible for providing the necessary strategies to define what is indicated for patients with venous ulcers. Moreover, by introducing clinical thermography in the evaluation and monitoring of these patients, this professional will contribute to better accuracy and reduce the subjectivity of the evaluation.

In this context, the present study aimed to analyze the temperature of the venous ulcer compared to the temperature of the healthy contralateral limb and to evaluate whether this heat emission is associated with the severity of the lesion.

Method

This is an analytical cross-sectional study using the guiding model of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guide. The study took place from March to August 2021, involving people with venous ulcers in lower limbs who attended the dressing outpatient clinic of a private institution in Salvador, Bahia, Brazil.

Of the selected patients, 33 had VU in one of the lower limbs, resulting in a sample of 33 participants and 66 evaluated lower limbs: the limb with ulcer and the healthy contralateral limb, used as a comparison. The inclusion criteria were the person with venous ulcer in only one of the lower limbs and aged 18 years or more. The exclusion criterion occurred for people with VU of other etiologies.

The study variables were collected through a questionnaire with information about sociodemographic data (age, sex, race); anthropometric data; comorbidities, lifestyle, time of venous ulcer, and relapses; injury evaluation (clinical and PUSH score); and the thermographic evaluation, that covered the temperatures of the lesion (center, edge, and leg), region above the lesion and homologous areas of the contralateral limb — areas defined according to the need to delimit the area in which the temperature needs to be studied.

The infrared camera FLIR One Pro® was the equipment used to collect the thermographic images and, as directed by the *Manual de Termografia Médica: Based on the International Consensus and Guidelines for Medical Thermography*[30], the images were captured in a controlled environment with an average temperature of 22 ºC and relative humidity below 60% (Digital Hygrometer Thermometer with external sensor (DC103), brand OKSN@.), also with artificial lighting by fluorescent lamps, as well as the maintained distance of approximately 50 cm between camera and venous ulcer; the same distance was respected for the homologous areas in the contralateral limb.

Data collection occurred at two distinct moments. The first began after the patient's acceptance to participate in the research, reading, agreement and signature of the informed consent form (ICF), and application of the questionnaire, in which the answers to all the questions were freely chosen.

In a second moment, a specialist nurse, belonging to the service, evaluated the injury. The evaluation occurred after dressing removal and before any procedure, when patients remained for 10 minutes with the lower limbs at rest, followed by the capture of thermographic images of the areas of VU and contralateral limb, according to the protocol of standardization for the collection of thermographic images created by the author using the *Manual de Termografia Médica*[30] as a base since nothing was found in the literature for thermographic collection in venous ulcers.

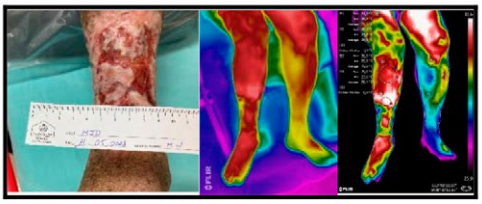
The treatment of thermographic images and data analysis occurred from the static images in the format of a radiometric .jpeg file. Automatic analysis of the temperature distribution of the regions of interest was performed, and the images were analyzed using FLIR Tools®. Following the guidelines of the Manual[30], the Rainbow High Contrast (HC) color palette was chosen, and the emissivity was adjusted at ε = 0.98. The definition of the temperature range depends on each participant due to the clinical conditions of the lesion, being equal for the limb with VU and healthy contralateral limb.

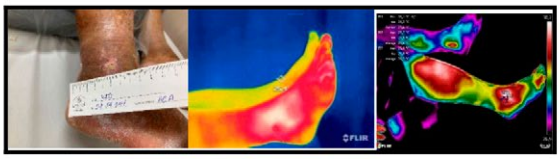
The temperature measurements obtained from the thermography for the leg ulcer were: maximum and average ulcer temperature; center, edge, and leg. The same measurements were performed in the homologous regions of the healthy contralateral limb. The maximum temperature between regions of the lesion and contralateral constituted the variable Delta of temperature (ΔTmax).

The lesions, by means of thermography, can be classified as isothermal (little or no thermal variation) or anisothermal (varied thermal distribution); defined by the shape of the lesion (geographical, discoid) and how it appears (poorly delimited, well delimited).

Figure 1- A and 1- B shows the ulcer and leg areas whose temperatures were measured.

Figure 1- A and 1- B. Lower limb thermography (n=66) demonstrating temperatures in the ulcer and leg areas – Salvador, BA. Brazil, 2021

1- A 

1- B 

Source: the authors (2023).

Using the SPSS, the data were presented as descriptive statistics, using absolute and percentage numbers for discrete variables and measures of central tendency and dispersion for continuous variables. The thermographic variables were compared between the two groups and compared with clinical and sociodemographic data. The chi-square test was used for the hypothesis test in the case of dichotomous variables; Student's t-test and Pearson's correlation were used in the case of continuous variables (normality confirmed by the Shapiro-Wilk test).

The study was approved by the Research Ethics Committee of the *Santa Casa de Misericórdia* of Bahia (CAAE 43302621.5.0000.5520), and all participants signed the ICF after agreeing to participate.

Results

The main sociodemographic, anthropometric characteristics and presence of comorbidities of the participants are presented in Table 1, which shows a population with a mean age of 70±12.5 years, higher frequency of males (17; 51.5%), body mass index (BMI) compatible with obesity (17; 50.0%) and mixed race (14; 42.4%). Regarding the presence of comorbidities, 7 (21.2%) had a diagnosis of diabetes, 6 (18.2%) of cardiopathies, 2 (6.1%) of cerebrovascular accident (CVA), and 20 (60.6%) of arterial hypertension (SAH). Among the 33 participants, 2 (6.1%) were smokers, 10 (30.3%) had the habit of drinking, and 9 (27.3%) reported performing physical activity.

Table 1. Sociodemographic, anthropometric, lifestyle, and comorbidities characterization of participants in the Dressing Outpatient Clinic, Salvador, Bahia, Brazil, 2021 (n=33)

Variable	Mean (SD)	N (%)
Age (years)	70 ± 12.49	
Sex		
Male		51.5% (n=17)
Female		48.5% (n=16)
Race		
Brown		42.4% (n=14)
Black		36.4% (n=12)
White		21.2% (n=7)
Alcoholism		30.3% (n=10)
Smoking		6.1% (n=2)
Height (m)	1.68 ± 0.115	
Weight (kg)	82.4 ± 17.58	
BMI (kg/m^2)	28.96 ± 4.96	
Normal		30.3% (n=10)
Overweight		18.2% (n=6)
Obesity		51.5% (n=17)
Comorbidity		
Diabetes mellitus		21.2% (n=7)
Arterial hypertension		60.6% (n=20)
Cardiopathy		18.2% (n=6)
CVA		6.1% (n=2)

Source: research database Clinical Application of Thermography in the Evaluation of Clinical Signs of Lower Limb Venous Ulcers.

Most participants (32; 97%) walked normally. Concerning time with ulcer, more than six months was found in 29 (87.9%) cases. Recurrent ulcers occurred in 23 (69.7%) cases; the PUSH score ≥12 was found in 21 (63.6%) lesions.

In the morphological analysis, the PUSH score ≥12 was associated with the geographic form (83.3% - p=<0.001) and poorly delimited (74.1% - p=0.008). In the extension of the lesion ≥50 cm², there was an association in the geographical form (45.8% - p=0.045) and anisothermal (47.4% - p=0.046) (Table 2).

Table 2. Comparison between lesion extension and PUSH score versus morphological image. Participants (n=33), Dressing Outpatient Clinic, Salvador, Bahia, Brazil, 2021

Variables	N	Predominant morphology	Percentage	P
PUSH				
≥ 12	20	Geographic	83.3%	<0.001
≥ 12	20	Poorly delimited	74.1%	0.008
Extension (cm²)				
≥ 50 cm²	11	Geographic	45.8%	0.045
≥ 50 cm²	9	Anisothermal	47.4%	0.046

Source: research database Clinical Application of Thermography in the Evaluation of Clinical Signs of Lower Limb Venous Ulcers.

The maximum and average temperatures of the limb with VU were higher compared to the contralateral limb (healthy) in the studied regions (lesion, center, edge of the lesion and leg, region above the lesion), presenting p<0.001 in all regions, represented in Table 3.

Table 3. Comparison between maximum and average temperatures of the limb with ulcer versus maximum and average temperature of the contralateral limb of participants (n=66), Dressing Outpatient Clinic, Salvador, Bahia, Brazil, 2021

Thermal characteristics	With Ulcer	Without Ulcer	P
Maximum temperature			
Leg	31.17 (±2.53)	30.30 (±2.27)	<0.001
Lesion	31.49 (±2.09)	29.67 (±2.77)	<0.001
Edge	31.22 (±2.15)	29.36 (±2.80)	<0.001
Center	30.51 (±2.01)	29.13 (±2.69)	<0.001
Average temperature			
Leg	30.41 (±2.66)	29.66 (±2.54)	<0.001
Lesion	30.32 (±2.16)	28.77 (±2.60)	<0.001
Edge	30.69 (±2.18)	29.11 (±2.75)	<0.001
Center	29.96 (±2.03)	28.84 (±2.69)	<0.001

Source: research database Clinical Application of Thermography in the Evaluation of Clinical Signs of Lower Limb Venous Ulcers.

A significant thermal difference was found in the analysis of the lesion region (ΔTmax of the lesion) and leg region (ΔTmax of the leg) in relation to the VU recurrence and time >12 months, represented in Table 4.

Table 4. Comparison between general clinical data of the VU in relation to the Delta (ΔTmax) of the lesion and leg temperatures of the participants (n=33), Dressing Outpatient Clinic, Salvador, Bahia. Brazil, 2021

Variables	$\Delta Tmax$ of the lesion	p	$\Delta Tmax$ of the leg	p
Recurrence (n=23)	0.96 (±1.50)	0.004	0.48 (±1.18)	0.036
Ulcer time > 12 months (n=26)	1.25 (±1.72)	0.040	0.59 (±1.19)	0.106

Source: research database Clinical Application of Thermography in the Evaluation of Clinical Signs of Lower Limb Venous Ulcers.

When the maximum temperature was between 29.0 °C and 32.0 °C, there was simultaneously greater presence of epithelization tissue (33.3% with p=0.005) and greater time of ulceration when >1 year (58.3% with p=0.030). The average temperature between 30.0 °C and 33 °C was associated with alcoholism (45% with p=0.023) and hyperemic edge (50% with p=0.043). When the maximum temperature of the center of the lesion was 30.0 °C, there was also an association with alcoholism (43.5% with p=0.013) and hyperemic edge (47.8% with p=0.038). Asymmetry >1.0 ºC in our study was named severe Delta and was associated with the variables ulcer time when >1 year (66.7% with p=0.024), ulcer recurrence (57.1% with p=0.038) and alcoholism (42.9% with p=0.038).

Discussion

The results of this study indicated that there is a difference in temperature between the limb with a venous ulcer and the healthy contralateral limb, which refers to the relevance of the clinical application of thermography in the evaluation of venous ulcers in lower limbs. The thermal asymmetry between the limb with VU and the contralateral limb was positive in all regions studied: region of the lesion, edge and center of the lesion, leg, region above the lesion, and referred contralateral regions. All these regions presented average or maximum temperatures higher than the contralateral limb, with significance, as shown in Table 3. The center of the lesion (30.5 ºC) presented a lower temperature than the edge of the lesion (31.2 ºC) and the region of the lesion (31.5 ºC), corroborating the study by Monshipouri et al.[15] These authors report that the low temperature detected by thermography may be related to a slow healing process due to the decrease of oxygen in the affected area.

In the morphological analysis, performed in this study with the use of thermography, it was possible to verify significance between the venous ulcer with PUSH score ≥12 (p<0.001) and extension >50 cm² (p=0.045) as a lesion of geographical shape (irregular contour), 83.3% and 45.8%, respectively indistinct (74.1%), when PUSH ≥12 (p=0.008), and with irregular anisothermal distribution (47.4%) in the extension >50 cm² (p=0.008). This result, achievable by the thermographic map, allows for verifying the different temperatures presented in the lesion and relating them to the clinical picture of the patient. These results refer to the understanding of how thermography can assist in the clinical evaluation of VU in collaboration with the subjectivity of the evaluator's view.

All the characteristics of the ulcers promoted an increase in temperature in some evaluated region. The hyperemic border and the time of ulceration were associated with increased temperature in both the lesion and the leg. The increase in temperature can mean a risk of infection, ulceration, and even amputation, as it is a reliable marker of the inflammatory process.[22]

In the analysis of the time of ulceration, the ulcer with more than 12 months was also associated with the Delta (ΔTmax) of the lesion (p=0.040) and the Severe Delta (0.024), such as ulcer recurrence, which was related to the Delta (ΔTmax) of the lesion (p=0.004) and Delta (ΔTmax) of the leg (p=0.030) and Severe Delta (0.038). Alcoholism was associated with Severe Delta (p=0.038).

The mean age of 70 years found in the present study is an important aspect of the participants, since advanced age contributes to decreased vascular flow, compromises the supply of oxygen to the tissues, and, consequently, influences the healing process.[2] The habit of alcoholism promotes increased insulin resistance and glycaemia and causes changes in the healing process.[31] This habit was reported by 30.3% of the participants in this study.

In this study, thermal images of the VU area (lesion), center and edge of the ulcer, and region of the leg above the ulcer, when compared to those of the contralateral limb (healthy), allowed to find differences in temperature (Delta Tmax) with significance for all regions analyzed, which may alert to pathological changes[15] and the possibility of an inflammatory process, when the temperature result is higher in one of the limbs.[32] Cwajda-Białasik et al.6 show that thermography can contribute to the evaluation and prognosis of the lesion when the maximum temperature difference between the area with inflammation and the healthy area can reach the level between 1.5 ºC and 2.5 ºC.

Individuals considered healthy have thermal symmetry between the sides and a small difference in skin temperature (0.2 ºC86), which, among other factors, depends on the blood flow rate to remain normalized. It is noteworthy that variations caused by tissue damage or inflammatory process associated with the vaporization of the wound fluid can change the wound temperature.[33] Thus, the occurrence of thermal asymmetry above 0,3 ºC means possible abnormality[34] and can be considered a symptom of dysfunction suggestive of changes. In addition, it may indicate pathological abnormality when the difference is >1.0 ºC.[35,36]

In this study, significance was found only for asymmetry >1.0 ºC in relation to variables ulcer time >1 year, ulcer recurrence, and alcoholism. These occurrences refer to the alert to the severity of the disease when it is prolonged and, in parallel, the need for interventions that prevent this advance.

Among the limitations of the study is the fact that it was performed in a single center, which determined a relatively small sample. The research time may have limited the study in relation to new thermographic measures for comparison and better determination of conduct.

Conclusion

This study concludes that there is a difference in temperature between the limb with venous ulcer and the healthy contralateral limb in all regions studied, as well as proved that the temperature of the center of the lesion is lower than that of its edge.

The results indicate that it is relevant to monitor ulcer temperature because it is a quantitative indicator of thermal monitoring of inflammatory processes and tissue perfusion; it is a powerful non-invasive, painless, and accessible tool for clinical evaluation and thermal monitoring of venous ulcers.

Authors' contributions

Couto LDP and Matos MA worked on data acquisition, data analysis and interpretation, and statistical analysis. Calasans MT contributed to data analysis and interpretation. Silva JN and Araújo KOP participated in data collection. All authors worked on the conception and design of the research, critical review of the manuscript regarding the important intellectual content, and writing of the manuscript.

Conflicts of interests

No financial, legal or political conflict involving third parties (government, companies and private foundations, etc.) has been declared for any aspect of the submitted work (including but not limited to grants and funding, participation in advisory board, study design, manuscript preparation, statistical analysis, etc.).

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