Infrared images in the evaluation of the diabetic foot

Imagens infravermelhas na avaliação do pé diabético

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ABSTRACT

Introduction: Diabetes is a frequent pathology that has universal distribution. The incidence of the type 2 of this condition has been increasing with obesity. Early detection of dermatological, vascular, orthopedic and neurological origin pathologies helps the diagnosis and treatment of the diabetic foot.

Objective: To evaluate the feet of pre-diabetic and diabetic patients bearers of onychomycosis using thermography, aiming at identifying the vascular, neurological and orthopedic impairment, as well as following up the clinical development.

Methods: Capture of infrared images at baseline and after cold stimulus test, using an infrared sensor in a controlled environment.

Results: This examination allowed the suspicion of peripheral neuropathy of fine fibers to be raised, as well as to verify areas of footwear pressure and to evaluate the progression of Charcot foot.

Conclusions: Infrared imaging associated with dermatological examination can be a prophylactic tool for the early identification of vasomotor alterations in the soles, even in asymptomatic patients.

Keywords: Diabetic foot; Diabetes Mellitus; Thermography

RESUMO

Introdução: O diabetes é patologia frequente, de distribuição universal cuja incidência do tipo 2 vem aumentando com a obesidade. A identificação precoce das patologias de origem dermatológica, vascular, ortopédica e neurológica auxilia o diagnóstico e o tratamento do pé diabético.

Objetivo: Avaliar por termografia os pés de pacientes pré-diabéticos e diabéticos portadores de onicomicose, com o intuito de identificar o comprometimento vascular, neurológico e ortopédico, bem como acompanhar a evolução clínica.

Métodos: Captação de imagens infravermelhas basais e após teste de estímulo ao frio com sensor infravermelho em ambiente controlado.

Resultados: Esse exame possibilitou a suspeita de neuropatia periférica de fibras finas, áreas de pressão de calçados e avaliação da progressão do pé de Charcot.

Conclusões: O exame por meio de imagens infravermelhas associado ao exame dermatológico pode ser instrumento propedêutico para a identificação precoce de alterações vasomotoras nas plantas dos pés, também em pacientes assintomáticos

Palavras-Chave: Diabetes Mellitus; Pé diabético; Termografia

INTRODUCTION

Diabetes mellitus (DM) is a chronic disease that affects 18.6% of the elderly population in Brazil. Due to its high incidence, this disease is used as a model for the study of foot diseases. Dermatological changes affecting the feet are precocious and precede hyperglycemia, arising in the phase when there is an increase in the peripheral insulin resistance or in cases of obesity. Among them, the following stand out: dryness and desquamation, fissures in the heels, plantar intertrigo, callosities, onychomycosis and edema of the toes. These dermatological clinical
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Various types of organic processes are manifested by changes in diseases. Its use as a diagnostic method is based on the fact that quantifying and mapping skin temperature changes and defining certain red rays emitted between 8 and 12 μm by feet can be used to quantify and map skin temperature changes and define certain diseases. Its use as a diagnostic method is based on the fact that various types of organic processes are manifested by changes in the production of heat and changes in blood flow patterns in organs and tissues. Neurovegetative nervous system controlled thermoregulation of the skin governs the capillary and arteriovenous flow through central and peripheral activity. In the case of DM, sympathetic neurovegetative neuropathies result in the opening of these shunts and increased blood flow to the skin.\textsuperscript{3}

Plantar vasomotor alterations can be observed as they are influenced by the sympathetic neurovegetative system and the room temperature with assistance of thermography, performed with cameras or thermographic sensors, which record the patterns of the emitted heat through images termed thermograms. The goal is to thermally map the soles of the feet.

This mapping observes the concept of angiosomes, which are anatomical functional units grouped by regions that coincide with a particular vascular nervous territory.\textsuperscript{4–6} The six angiosomes of the feet and ankles are supplied by three main arteries: 1) the posterior tibial artery, which irrigates the plant of the foot (through the medial and lateral plantar branches) and part of the calcaneal region; 2) the anterior tibial artery, which irrigates the dorsum of the foot through the dorsal artery of the foot; and 3) the fibular artery, that irrigates the lateral border of the ankle. Only the dorsal plantar artery can be palpated in the clinical examination.

The objective of thermography is to capture infrared images emitted by the skin in order to record changes in the vasomotor control of the microcirculation and the arterial circulatory system, in this way mapping the area according to the distribution of angiosomes and plantar vasomotor reaction.\textsuperscript{7–10} Plantar morphological patterns are described according to the vascular anatomy of the lower limbs.

Infrared images also assist in the evaluation of infectious and traumatic intercurrences, among others. Diabetic foot ulcer is one of the most severe complications and early detection of its risk is crucial to preserve the foot. Thermography is used both to measure hyper-radiant areas with an acute increase in the plantar temperature, as well as chronic increases due to intensified arteriovenous flow.\textsuperscript{11–17} On the other hand, a chronic decrease in plantar temperature might indicate peripheral vascular disease, and instability in thermoregulation might lead to the suspicion of diabetic neuropathy.\textsuperscript{18} This variation can be assessed using the provocative cold stress test, performed with the exposure of the feet at 15°C, where thermal reheating can be observed after 10 minutes, promoted by reactive hyperemia in the plantar region. Analysis of the images performed by a specialized digital imaging software makes it possible to measure the reheat reaction with a 0.2°C accuracy, yielding a comparative curve between the feet.\textsuperscript{19}
2018. The study complied with the ethical criteria of the Helsinki Declaration. The capture of infrared images (thermograms) was performed in a controlled environment (room temperature at 23°C, and air circulation < 0.2 m/s) using a hypersensitive infrared sensor (18mm, 320x240 pixels resolution), Flir T420® (Flir Brasil, Sorocaba, São Paulo, Brazil). The baseline thermograms of the plant and dorsum of the feet were evaluated with a cold stress test, with immersion of the feet in water at 15°C for one minute and subsequent plantar registration after 10 minutes. The images were analyzed with assistance of the software Flir Tools® (Flir Brasil, Sorocaba, São Paulo, Brazil), with the measurement of the maximum, medium and minimum temperatures of the demarcated areas. Initially, the thermal pattern of the feet’s dorsa and plants was observed, which should follow a thermal gradient pattern with hyper-radiation in the plantar arch and reduction of this radiation in the periphery, characterizing the butterfly pattern (Figure 1). Next, the forefoot, midfoot and hindfoot areas were measured according to the vascular territory of the anterior and posterior tibial arteries and their ramifications. Finally, the measurement of the toes was performed aimed at verifying the difference in temperature (ΔT), which is expected to be ≤ 0.4 °C, even after the cold stress test.

**RESULTS**

Four male and 5 female patients with DM and chronic onychomycosis, aged between 39 and 88 years, without history of foot ulcer (Wagner’s ulcer Grade 0) were included in the present evaluation. Two patients (one with DM1 and one with DM2) underwent cold stress tests, aiming at enhancing the vasomotor reaction through cold stimulus. All evaluated patients were considered positive for abnormal sympathetic vasomotor instability in the feet, as they presented breakage of the transverse lines of the distal thermal gradient of the feet, as well as interdigital anisothermy ≥ 0.4°C – with or without the cold stimulus test (Figures 1 and 2). The patterns of plantar thermography varied according to the classification based on the anatomical units (angiosomes). A large increase in the area of plantar hyper-irradiation was observed in two T2 DM and Charcot foot bearer patients (aged 68 and 88 years), with one of the cases presenting recurrent paronychia, lymphedema and erysipelas, confirmed with ΔT above 3°C as compared to the contralateral limb (Figures 3a, 3b, 3c). The cases evaluated by thermography did not present poor vascular perfusion or ischemia – even in the hypothetic presence of those conditions, Nd:YAG laser would be contraindicated in the treatment of onychomycosis.

**DISCUSSION**

Peripheral neuropathy is a common complication in diabetic patients, affecting more than 50% of that population.1 This condition increases the risk of ulcerations that can lead to lower limb amputation. The patients examined did not had ulcers in the lower limbs, having therefore been considered grade 0 both by the Wagner’s and the University of Texas’ classification systems, used in the evaluation of the diabetic foot.1,8 Infections or ischemia increase the risk of amputation, which suggests that diagnosis and regular follow-up decrease the morbidity and mor-

\[\text{Figure 1: Seven} \text{ty-five year-old male patient bearer of DM1, hypertension; onycholysis in the right hallux (coinciding with the jogging shoes’ pressure area); dryness and fissures in the calcaneal region, which might have occurred due to peripheral neuropathy of fibers (reduction of sweating),}\]

\[\text{A - Fifty-nine year-old male patient, bearer of DM1, hypertension; onycholysis in the right hallux (coinciding with the jogging shoes’ pressure area); dryness and fissures in the calcaneal region, which might have occurred due to peripheral neuropathy of fibers (reduction of sweating),}\]

\[\text{B - Hyporadiant area in the right hallux (region of vascular suffering, coinciding to the jogging shoes’ pressure area); breaking of the transverse lines of the thermal distal of the feet and digital anisothermy with hyper-radiation in the fifth metatarsus.}\]

\[\text{C – Breakage of the transverse lines of the distal thermal gradient of the feet and digital anisothermy (ΔT > 0.3 °C, between the distal phalanges of the toes and hyper-radiation in the fifth left and right metatarsus); clinical history of L5-S1 lumbar hernia treatment, presents hypo-radiation bilaterally in the calcaneal region, characteristic pattern of neural root involvement at S1}\]
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Figure 3: A – Sixty-eight year-old woman, bearer of DM2, hypothyroidism; clinical examination indicated a chronic lymphedema in the lower limbs and paronychia in the right hallux, drop in the plantar arch, loss of ankle dorsiflexion, ankle contracture, which are alterations commonly found in the Charcot’s foot, confirmed by the radiological alterations found (subluxation of distal articulation of the right hallux, increase of soft parts, among others); thermography. B – Breakage of transverse lines of the distal thermal gradient of the feet with hyper-radiation throughout the soles, more pronounced in the left foot; pattern observed in cases of plantar circulatory and/or vasomotor alterations (peripheral neuropathy of fibers). C – Presence of hyper-radiation with ΔT > 4.2 °C when compared to the right and left halluces, with ascending pattern suggestive of lymphangitis; the infrared image accompanied by clinical examination confirmed the diagnosis of paronychia.

The cold stimulus test followed by infrared imaging is used due to the fact it significantly increases the sensitivity of the method, and is indicated in tandem with ambulatory exams performed when there is complaint of burning feet, signs of increased peripheral insulin resistance or of increased glucose tests in asymptomatic patients, or still when there are cutaneous signs of neurovegetative neuropathy.19 The reactive hyperemia response can be measured and depicted on a graph used to monitor treatment. However, it is important to note that loss of fine nerve fibers can occur in other diseases, such as fibromyalgia syndrome, motor neuron disease, Ehlers-Danlos syndrome and Parkinson’s disease, among others,19 isolated or associated with diabetes. The clinical examination of the feet in the studied group showed areas of plantar dryness and desquamation, hyperkeratosis and plantar arch drop (Charcot’s foot in two cases), in addition to steppage gait, associated with the results of basal thermography, evidencing areas of plantar hyper-radiation in the regions where there was frequent contact with footwear and inadequate tread (Figure 4). In diabetic patients, fine fibers neuropathy may gradually combine with that of large fibers in type 2 diabetes patients, and generally affect the distal extremities in the upward direction.19 Patients may experience burning sensation, stinging, pruritus in the lower limbs in addition to cramps and restless legs during the night.2 It may be accompanied by other neurovegetative symptoms, such as changes in sweating, diarrhea, constipation, dry eyes, palpitation, hot flashes, sensitive skin, burning feet and heat intolerance. Other tests may be necessary to confirm the diagnosis of diabetic peripheral neuropathy, by applying neurological protocols and performing skin biopsy with 3mm punch followed by histological examination with special stains, aiming at assessing adnexa and quantifying nerve fibers in the dermis.2

CONCLUSION

Infrared imaging of the feet may be a useful propaedeutic tool alongside ambulatorial clinical examination, as it provides assistance in the mapping of the lower limbs – in special the plantar region – in the preliminary and early diagnosis of fiber neuropathy and in the identification of areas of infection and poor blood perfusion, aiding in the preparation of differential diagnoses and aggravating risk factors already in the first ambulatorial clinic visit or at the dermatologist’s practice.
REFERENCES


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