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Investigation of peripheral vascular disorders using thermal imaging

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Abstract

Infrared thermal imaging has been used to study non-invasive diagnosis of peripheral vascular diseases. Temperature gradients indicating abnormal blood flow in the affected regions of patients with vascular disorders are well correlated with clinical findings. The temperature in the affected regions was about 0.7–1°C above the normal regions, due to slow blood circulation. Thermal imaging is an effective technique for detecting small temperature changes due to vascular disorders, it is non-invasive, portable, compact and safe.

Introduction

Temperature is an important and useful parameter for diagnosis of various diseases.[1] The correlation of body temperature and diseases has been known for centuries but in recent years, due to advent of new technologies, skin temperature has been used as a convenient and effective diagnostic tool.[2] Human body temperature has been recorded with thermocouples, thermistors and thermopiles, for almost 60 years, but these sensors are very large, slow in response and difficult to attach to the skin.[3] The first documented application of thermography was for early pre-clinical diagnosis of breast cancer in 1956.[4] Infrared thermal imaging has been used to study blood flow, detection of breast cancer and muscular performance[5,6] and quantify sensitive changes in skin temperature in relation to disease.[7] The temperature of extremities is largely dependent on peripheral blood flow vessels hence this imaging tool is useful in vascular diseases.[8] Blood flow can also be assessed by many methods including washout technique and laser Doppler flowmetry.[9] Infrared thermography has the advantages of being non-invasive,[10] fast, reliable, non-contact, capable of producing multiple recordings at short time intervals and is safe for patients and doctors. In all the studies reported herein, only relative and not absolute temperatures are significant and the relative temperatures have to be measured at many points on the skin, and in this sense, the infrared sensing device has many advantages over conventional devices.[11]

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Methods and results

Preparation of subjects for the study

All subjects had a long history of vascular disorders but none had diabetes. The body region investigated was the area where patients reported aggravated pain. Thermal images of this region were compared with those from the same region of the unaffected limb from a normal individual. Details of experimental subjects are presented separately.

All subjects rested in a room where the relative humidity and room temperature were controlled (to achieve equilibration of body temperature with the ambient temperature). All the selected patients had a prolonged history of vascular disorders and were non-diabetic. No parts of the subjects were in contact with any hot or cold sources and were not near air convection sources. These precautions have been taken to minimise the variables that might influence temperature measurement.

Each subject underwent a thorough medical examination and a clinical report was recorded. Room temperature was maintained by a wall mounted air conditioning unit. The body region being invesigated was disrobed 15 minutes prior to imaging by an infrared thermal camera positioned one metre away. The same region was continuously monitored on a colour display unit with pseudo colour, making temperature changes easily discernible. Same views of the corresponding contralateral region of the patient and of normal controls were also taken.

Experimental details

Thermal imaging was carried out using Thermovision-550 system (PtSi Focal Plane Array with a spectral range of 3.6–5 µm). The temperature range of the camera is 253–1473 K with a resolution of 0.1 K and employs Stirling type cooling. It has a 12-bit digital image storage with image size of 151 kB. The surface temperature profiles of the patients were recorded and later analysed using image processing software. The thermal profile of the area of examination was compared with the counterpart region of the same patient and same region of a healthy volunteer. Using a spot metre, area and profiling

tools, the change in the temperature was determined. The region of the body that was getting aggravated pain was chosen as the region of interest based on the medical history of the patient.

Case reports

Patient 1

A 28-year-old male, with a history of pain in the left lower limb, which was aggravated on prolonged standing. He had varicosity of the long saphenous system of the left lower limb and was suffering from complications of varicosity for the past one year. He was using crepe bandages. Local examination of the lower limbs showed dilated tortuous veins in the dorsum of the left foot and dilated veins in the dorsal aspect of the foot extending up the lower one-third of the right lower limb.

From the thermal images, (figure 1) it can be seen that a lower temperature is noted at the distal portion. This is probably due to slow-moving blood circulation in the toes, venous drainage being inadequate due to the varicosity. The temperature in these regions was on average 0.7–1°C above the normal regions. The abnormal temperature is due to varicose veins. A uniform temperature would be seen in the leg of a normal person.

Patient 2

A 31-year-old male, with a five-year history of swelling in both the lower limbs on prolonged standing had recurrent ulceration over the left lateral malleolus associated with pain and discharge of pus. The patient had undergone treatment and surgery four years previously for the same complaint. Local examination of the left lower limb showed tortuous dilated veins, recurrent healing ulcers covered with slough and pus discharge on the left lateral malleolus. In the right lower limb, dilated tortuous veins, mild oedema and scars were noticed over the right ankle joint. The palpable arterial pulse was normal. The patient had systemic hypertension noted six months ago for which he was receiving medication.

Varicosity appears as areas of increased warmth in thermal images. From the thermal images (figure 2), the warm areas are noted on the lateral side of the left leg as well, an unusual finding, because most patients have varicosity located only on the medial side of the leg. The distal region near the toes (indicated by white arrow in figure 2b) is blue (lower temperature) due to the poor perfusion of blood and is attributed to stasis of circulation due to varicosity. The thermal image shows a higher temperature due to the tortuous venous carrying warm blood at a slow-moving speed when compared to normal venous drainage. The temperature changes observed on the patient are not seen in the leg of a normal person.

Patient 3

A 48-year old male had pain in the left calf muscle for two years being severe for the past six months. He had a history of pain on walking being relieved by rest. On prolonged standing the pain increased. Pulses were normal in the right and left upper and lower limbs. The *dorsalis pedis* was normal in the right and of feeble low volume in the left lower limb, the posterior tibial pulse was normal on the right and of low volume on the left. The patient is an occasional smoker and user of alcohol. There was an injury in the left big toe eight months ago. He had a non-heeling ulcer on the left great toe and gangrenous tissue was also observed.

From the thermal image (figure 3), the left leg medial view of the patient shows elevated temperatures because of thrombosis. It is an arterial obstruction. The area represented in the thermal image as a warm area (figure 3) corroborated reports of severe pain in the calf muscle. These temperature changes are not seen in the thermal image of a normal person.

Figure 1. a: Thermal image of patient's left leg; **b:** isothermal image of right leg, with varicose veins and line profile along the toes is inset

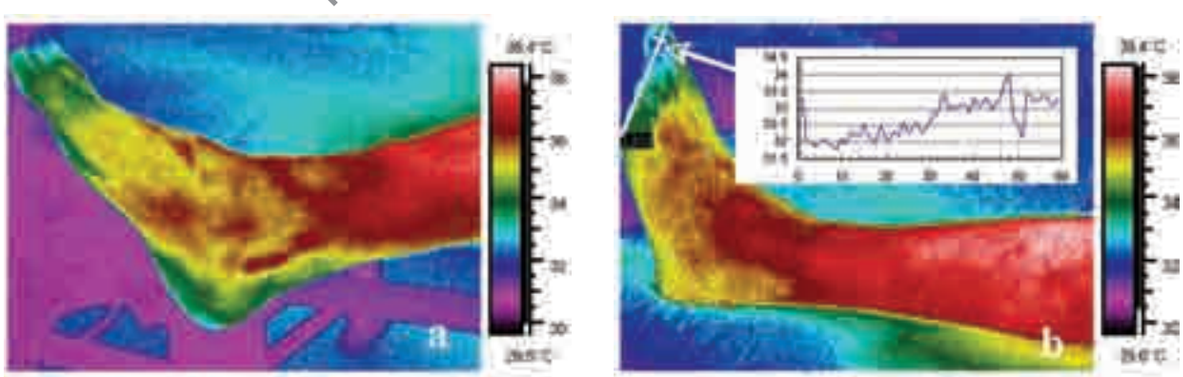


Figure 2. Thermal image of **a:** normal dorsal **b:** interior normal view of affected patient's left leg

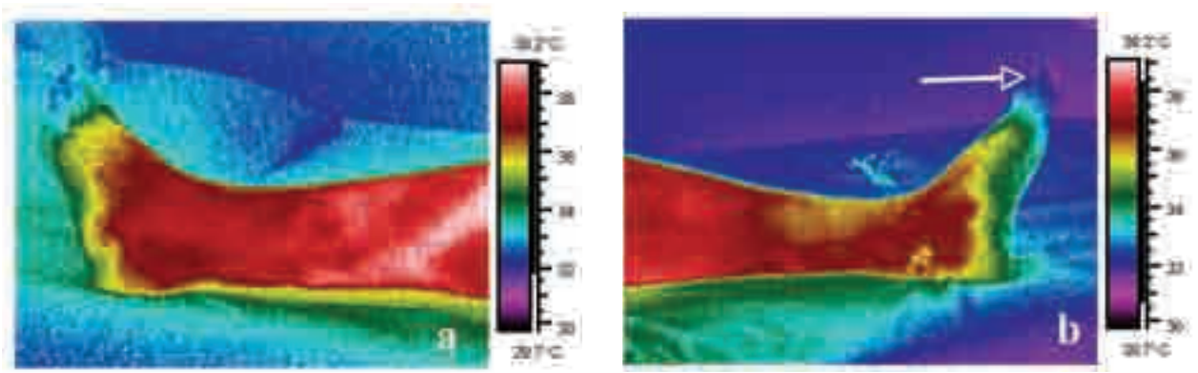
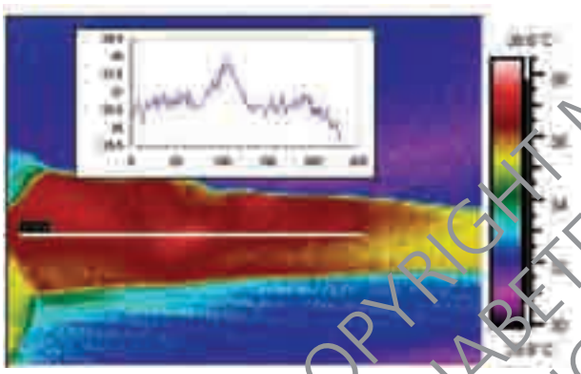


Figure 3. Thermal image dorsal view and line profile of affected patient left leg



Conclusion

Thermography coupled with clinical findings is used for medical diagnosis of vascular disorders. Temperature gradients are observed in the affected regions of patients with vascular disorders and ischaemic gangrene, indicating abnormal blood flow in the affected region, which is well correlated with the clinical findings. The temperature in the affected regions was about 0.7–1°C above the normal regions, due to slow blood circulation. The abnormalities are not observed in the same regions of healthy volunteers and normal contra-lateral limbs of the patients, demonstrating the usefulness of thermal imaging for medical diagnostics with high reliability.

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