



USING INFRARED THERMOGRAPHY IN MEDICINE

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ABSTRACT

Thermography is a non-invasive, non-radiative, non-contact skin surface temperature screening method that is economic, quick and does not inflict any pain on the patient. It is a relatively straightforward imaging approach that detects the variation of temperature on the human skin surface. Thermography is widely used in the medical arena: female breast, rheumatology and orthopedics, neurology, vascular imaging (arterial and venous) and other.

The infrared thermography has become a welcome additional measuring method for the physician, being able to measure and pursue surface temperatures contact-free statically and dynamically. Infrared imaging is a low cost detection tool, and its application area is constantly growing, along with technical improvements and advances. With the cooperation of physician and technical engineer thermography has entered already many fields of human medicine and will open account of its strong advantages even more areas.

Key words: Infrared thermography; IR-imaging; skin temperature; non invasive; medical application;

INTRODUCTION

The medical use of infrared thermography started shortly after 1950 in Germany, where long time before Prof. Czerny in Frankfurt am Main presented the first infrared image of a human subject (1928). In the beginning, single IR detectors have been used. Due to the development of other thermographic devices like contact thermography by electronic thermometers and by LC (liquid crystal) plates they were integrated in medical diagnostic systems.

In 2007 the first medical infrared imaging systems (MammoVision, ReguVision and FlexiVision by InfraMedic) have received a CE certification allowing to be used as thermal measuring medical devices (Category 1) and matching the European Medical Directive legislation. Other devices without medical CE certification are limited to be used as imagers only without measurement functions and without temperature reading.

Qualified medical infrared imaging covers a broad field of applications: female breast, rheumatology and orthopedics, neurology, vascular imaging (arterial and venous), occupational (vibration related vasospastic syndrome), forensic, surgery, and full body screening including thermal stress response

examinations (IRI – Infrared Regulation Imaging).

Medical Infrared Thermography (MIT) is a non-radiating and contact-free technology to monitor physiological functions related to skin temperature control. The efficiency, safety and low cost of MIT make it a useful auxiliary tool for detecting and locating thermal abnormalities characterized by increases or decreases in skin surface temperature.

Most of the diagnostic imaging modalities in medicine utilize portions of the electromagnetic spectrum (**Fig. 1**) However, in contrast to other medical devices, MIT uses non-ionising radiation, thus allowing an unconstrained and harmless application in patients. Using infrared radiation, infrared cameras generate thermal images based on the amount of heat dissipated at the surface. Roughly 80% of the emitted infrared radiation of human skin is in the wavelength range of 8-15µm. The technology operates in the long-wave infrared region and is a sophisticated way of receiving electromagnetic radiation and converting it into electrical signals. These signals are finally displayed and matched to colors on the screen for calculations. Modern focal plane array detectors ensure a stable image with high thermal resolution. Sensitivity and resolution are important parameters for medical devices.

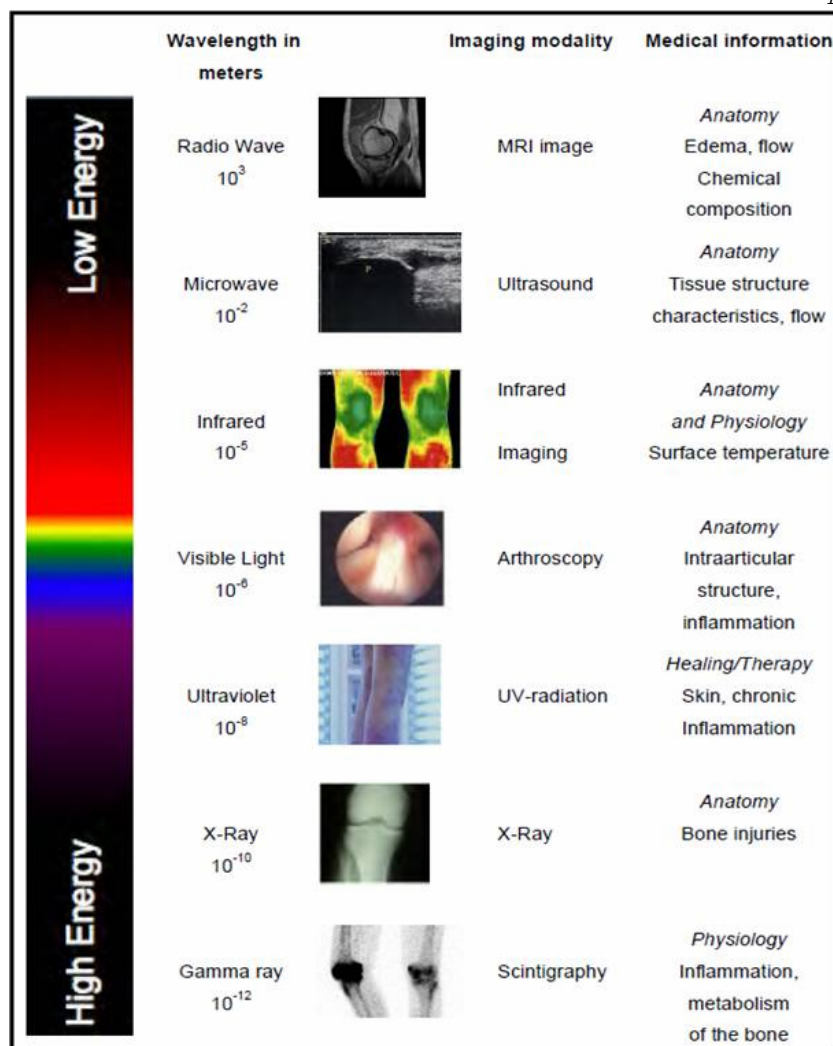


Fig. 1. Medical imaging modalities within the electromagnetic spectrum

There is a growing chance for infrared thermography in modern medicine. IR thermography has a high diagnostic specificity and, therefore, is able to identify health as well as first deviations of the ideal health state. The recent shift of the traditional medical paradigm (diagnose and treatment) to a more modern approach (identify risks and eliminate them) and, even more, identify health and help keep it, opens new horizons for IR thermography.

Body heat is generated by metabolism and by muscular activity and keeps the core temperature at a defined, slightly oscillating level (about 37 °C). The organism's heat loss depends on ambient factors and results of conduction, convection, IR radiation, and of evaporation (sweating) of the surface, the skin (despite of breathing and other mechanisms, Fig. 2). Inside the organism heat is transported by convection (blood flow) and by conduction.

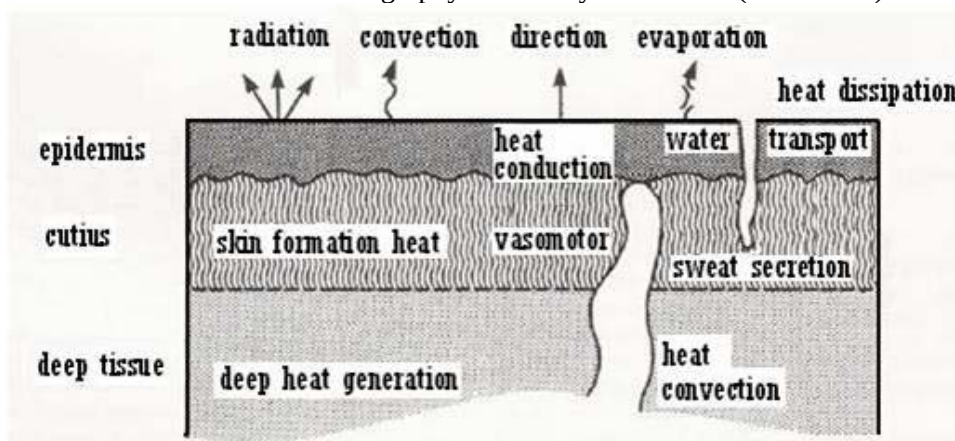


Fig. 2. Mechanisms of heat loss at the human body surface

The thermal pattern of the surface (skin) under defined laboratory conditions is far from arbitrary. It is the result of different synergistic and antagonistic factors and processes, well described by human physiology and pathophysiology.

According to PLANCK's law the dry human skin, nearly an ideal blackbody (Emissivity 0,98), is a long wave IR radiator with a maximum emission at about 10 μm .

Infrared radiation is emitted from objects with a temperature above absolute zero. The human body radiates heat energy from the surface of the skin and the emissivity of human skin is 0.98, which is close to that of a perfect black body. Therefore, accurate temperature values can be created from measurements of the infrared radiation from the skin. Infrared thermography is the recording of temperature distribution of a body using the infrared radiation emitted by the surface of that body at wavelengths between 0.8 μm and 1.0 μm . An infrared camera is used to detect the infrared heat energy that is emitted from the skin. The amount of the energy that is recorded is converted into an energy signal that, along with other parameters, is used to calculate the actual temperature of the object. With this information it is possible to create a visual map or thermogram of the distribution of temperatures on the surface of the object imaged. The sensitivity of modern infrared cameras is such that temperature differences to 0.025°C can be detected.

Breast Thermography

Breast infrared thermography is a noninvasive procedure that does not involve compression of the breast tissue or exposure to X-ray radiation, and functions through an assessment of physiological function, through high resolution temperature measurements of breast tissue.

Breast cancer is the most commonly occurring disease in women and the mortality rate due to breast cancer is high . It is because tumor becomes fatal when detected in the last stages of

development. On the other hand if it is detected earlier then it can be treated and mortality rate can be reduced. Though mammography is the well established technique for breast cancer diagnosis, it can not detect it at the early stage. Clinical Infrared thermography is now accepted as the reliable technique for early detection of breast cancer followed by further investigations. Infrared thermography results in thermographs which are obtained by mapping the temperature distribution on the breast surface.

The underlying principle behind thermography is that cancer cells require large amount of nutrients for its growth and hence results in higher metabolic activity around that region. As a result, temperature increases in that area when compared to the other regions. It introduces asymmetry in the otherwise symmetrical distribution of temperature in left and right halves. Severity of the disease can be determined by measuring the temperature variations in the abnormality region. Better detection necessitates high end Infrared camera that gives a high quality thermograph. Due to recent advances in Infrared technology, specifically designed focal array planes are available for obtaining high quality thermographs. Later these thermographs can be quantitatively analyzed for abnormality detection and classification.

Example of an normal and abnormal breast thermal image obtained from women volunteers are shown in **Figs 3a and 3b**. Temperature distribution between left and right parts of the breast was symmetrical for a normal case (**Fig. 3a**) (as the colour pattern is symmetrical). There will be rise in temperature of the breast skin surface area above the existence of cancerous mass. Thermogram of an abnormal case (**Fig. 3b**) showed asymmetrical colour pattern. Her self breast examination showed lump in her left breast part, so she reported to clinic for further examination. MRI scan report of this woman confirmed having cancerous mass in left part of the breast. In the thermal image, left part of the breast showed the increased surface temperature when compared to right part of the breast. Further, biopsy test conducted on this patient also proved lump as malignant neoplasm.

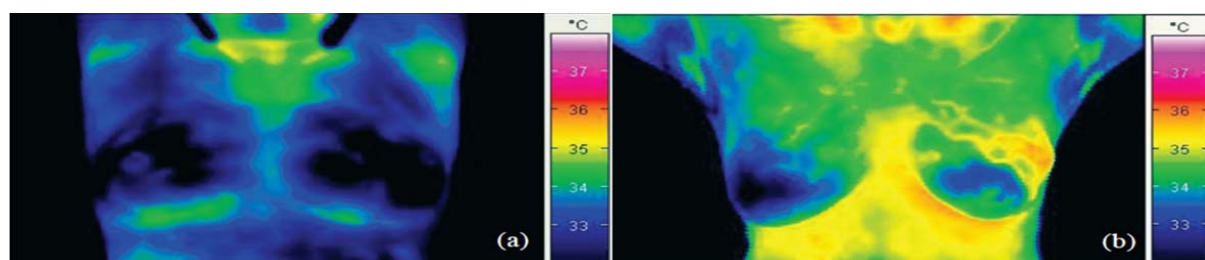


Fig. 3. (a) Normal and (2b) abnormal breast thermogram

Infrared Imaging for Emergency Medical Services-using an IR camera to identify life-threatening emergencies

• Airway

If the patient's airway is blocked, oxygen cannot reach the lungs and so cannot be transported round the body in the blood. Ensuring a clear airway is the first step in treating any patient. Common problems with the airway involve blockage by the tongue or vomit. In most tissues of the body, the response to hypoxia is initial vasodilation. By

widening the blood vessels, the tissue allows greater perfusion. But the extremities turn cold due to his lower metabolism, allowing the brain to withstand a much longer period of hypoxia. As **Fig. 4** shows, although this thoracic trauma patient had been intubated his temperature rapidly fell 2.7 °C compared to the nurse as identified by IR imaging because obstruction of his endotracheal tube by serum-bloody pulmonary secretions. The orotracheal airway was cleaned.



Fig. 4. IR image shows intubated patient with lower temperature than nurse due to obstruction of the Endotracheal tube

• Breathing and Ventilation

The injuries that may acutely impair ventilation and that should be identified in the primary survey are tension pneumothorax, flail chest with pulmonary contusion, massive hemothorax and open pneumothorax. **Fig. 5** shows how infrared imaging helped the team

to suspected of a pulmonary contusion caused by trauma at left thorax in an unconscious injured male. The red area indicates the troubled region and the spot meter points to the high temperature into the image coincident with fracture at 9th anterior left rib confirmed at ED by radiographies.

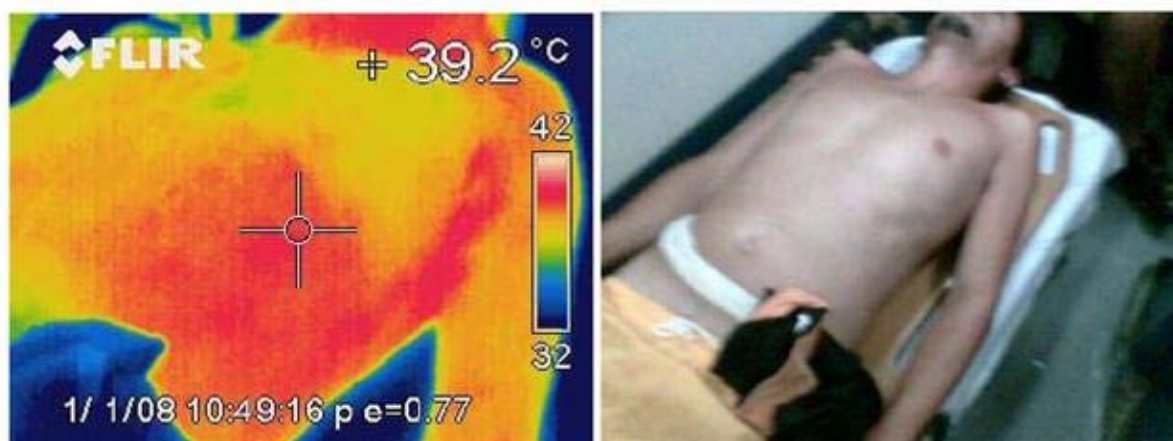


Fig. 5. IR image shows abnormal warming coincident with rib fracture

• Fractures

Trauma patients with long bone fractures induce a cascade of events which eventually lead to repair and homeostasis. This repair or wound healing involves three phases. The first phase, inflammation, is followed by tissue

regeneration and tissue remodeling. The inflammatory response is primarily intended to be a local response and provides protection for the host. It is characterized by classical clinical features such as rubor (redness), tumor (swelling), calor (heat), dolor (pain) and

function laesa (loss of function). Tissue damage surrounding the fracture will lead to disruption of blood vessels, thereby activating the coagulation cascade. Besides clot formation, coagulation induces the production of vasoactive, proinflammatory agents and activation of the complement cascade. Production of these mediators leads in turn to increased blood vessel permeability, local increased blood flow, induction of the expression of adhesion molecules and recruitment of cells into the site of inflammation. Of the various types of leukocytes that appear in the injured area

(neutrophils, monocytes, lymphocytes, macrophages) that produce cytokines and growth factors.

Thermography was a valuable adjunct to fracture diagnosis method as an early detection of soft tissue inflammation around it. It is particularly useful for the assessment of the bone regeneration as well. There is a direct correlation between the trauma intensity (fracture grade) and thermal indices as can be seen in **Fig. 6**, in this case of left distal femur fracture with increased local temperature.

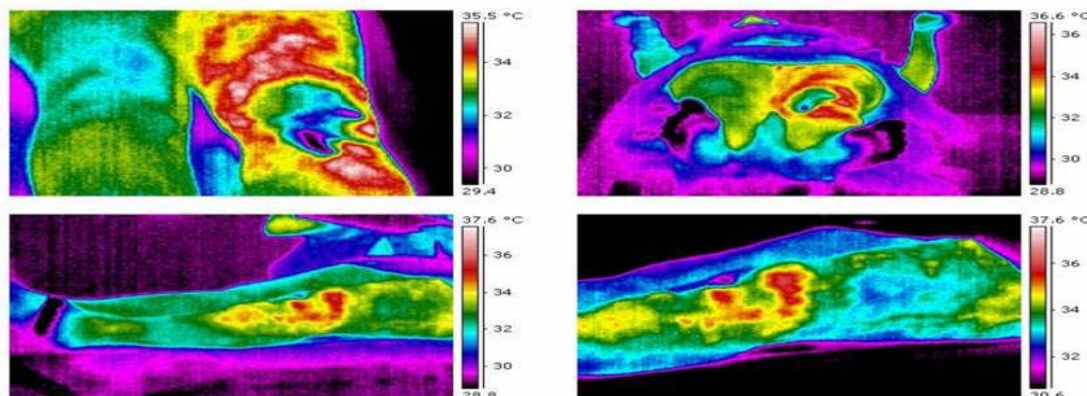


Fig. 6. IR images of left distal femur fracture showing increased local temperature

- Spinal cord trauma

Patients with severe high level spinal cord injuries present hot lower body extremities at trauma scene due to the massive vasodilatation occurring below the level of the injury which is attributed to a quickly decreased level of sympathetic activity (**Fig. 7**). High spinal cord injury impairs thermoregulation because it

disconnects the thoracic cord from central thermoregulatory centers thus preventing central control of cutaneous blood flow, sweating, piloerection and shivering. Above we documented a cervical trauma caused by diving into shallow sea water. This is the major cause of spinal cord trauma. He was attended at the beach.

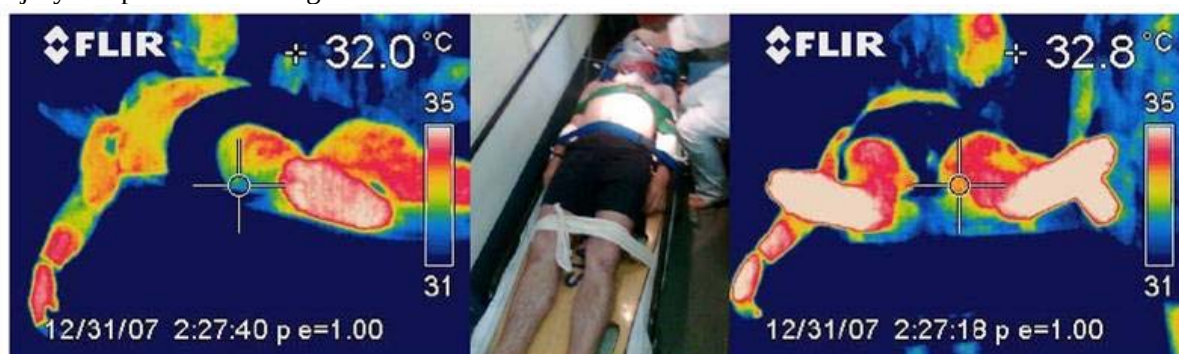


Fig. 7. IR images show abnormal heating of lower extremities due to spinal cord injury

- Heart attacks

Infrared thermography was used to measure and map precordial skin temperature in patients who suffered acute chest pain. All of them were confirmed coronary artery disease (CAD) in the hospital by angiography. The presence, mean area and degree of thermal

asymmetry were significantly greater in patients with CAD compared to normal. The results demonstrate that CAD is associated with precordial thermal asymmetry (**Fig. 8**). This resulted in a more fast diagnosis, conduct and transport of these emergency patients.



Fig. 8. IR image shows asymmetry and abnormal warming in patient with coronary artery disease

- Strokes

Many strokes are preventable and treatable with prompt medical attention. The cutaneous vessels of the medial forehead, medial canthus and supraorbital ridge are branches of the internal carotid artery. Under normal circumstances, there is a remarkable symmetry in the heat patterns from these regions. However, when the lumen of the internal carotid artery is significantly compromised, blood flow through these terminal branches is reduced and cooling of the forehead on the side

of the lesion can be detected. Associated with unilateral body IR hyporadiation (**Fig. 9**) it confirmed the acute carotid occlusion.

Thermography had its greatest use in detecting carotid occlusive disease among a group of high-risk, asymptomatic patients. Such patients include those with hypertension, diabetes and hyperlipidemia. Thermography was helpful to the physician to better interpret early the symptoms of cerebrovascular insufficiency making a quickly triage and assistance.

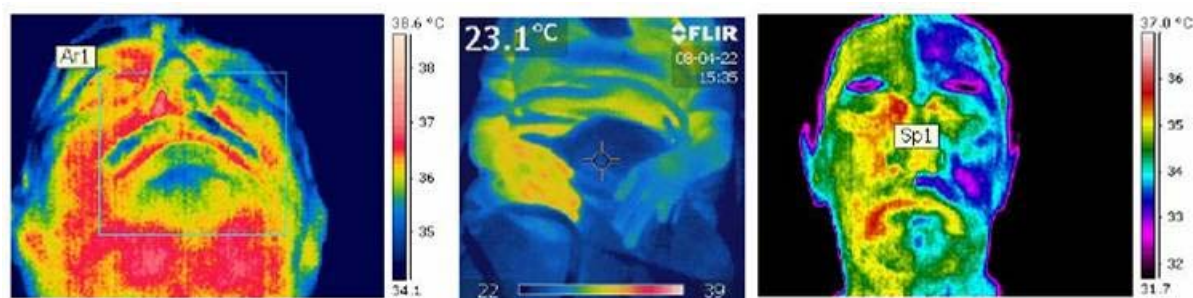


Fig. 9. IR images show cerebrovascular insufficiency indicating early symptoms of carotid occlusive disease. Left is thermal asymmetry in the face, center asymmetry in arms and hands and right another facial thermal asymmetry

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