Medical Thermography- Review of Literature

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Abstract

The intensity of the infrared radiation emitted by objects is mainly a function in accordance with their temperature. Infrared thermography is used for many purposes, like a health indicator in medical field, as malfunction indicator in electrical and mechanical maintenance or as an indicator of heat loss in buildings.

This paper focussed on two applications: measurement of temperature and non-destructive testing. An introduction to the above mentioned procedures are discussed here.

Keywords: Infrared thermography; active thermography; passive thermography; measurement of temperature.

INTRODUCTION

Infrared thermal imaging has been used in medicine since the early 1960's. Early imaging systems were highly inconvenient. Computer image processing of thermograms became available by early 1970's.This created an increased awareness for the need for standardisation of technique. Infrared thermography (IRT) deals with accession and processing of thermal information from non-contact measurement devices[1]. It is based on an electromagnetic radiation with wavelengths longer than those of visible light. Objects with temperature above absolute zero (i.e., T > 0K) produces infrared radiation[2] type of radiation. So infrared measuring devices are needed to receive and process this information[3]. Infrared radiation emitted by an object is acquired by infrared measuring devices and transform it into an electronic signal[4]. Pyrometer is the most basic infrared device. Advanced devices include an array of sensors. In infrared image, the scene is the source and can be observed by an infrared camera without light. By using infrared cameras the image captured are converted into visible images by assigning a colour to each infrared energy level. The result is a false-colour image called a thermogram[5]. IRT has many advantages over other technologies[6]. In general, the main advantages of IRT are the following:

- IRT is a non-contact technology.
- IRT provides two-dimensional thermal images.
- IRT has no harmful radiation.
- IRT is a non-invasive and painless procedure.

PRINCIPLE

Every object whose surface temperature is above absolute zero (0 K) radiates energy at a wavelength corresponding to its surface temperature. Highly sensitive infrared cameras are used to convert this radiated energy into a thermal image.

Objects above 0K radiates infrared energy. Emissivity is the relative efficiency of thermal radiation. Radiated energy (power) is proportional to the body's temperature, raised to the fourth power. This is known as Steffan-Boltzmann Law.

This energy can be measured and an instrument calibrated to indicate the corresponding temperature of the surface it is looking at. Instruments that scan an object and create an image or spatial map of surface temperatures are referred to as thermal imagers.

TYPES OF THERMOGRAPHY

1. ACTIVE THERMOGRAPHY

To produce a thermal contrast an energy source is required. The detection can be occurred hot either (active) or the cold (passive) spot on the surface.

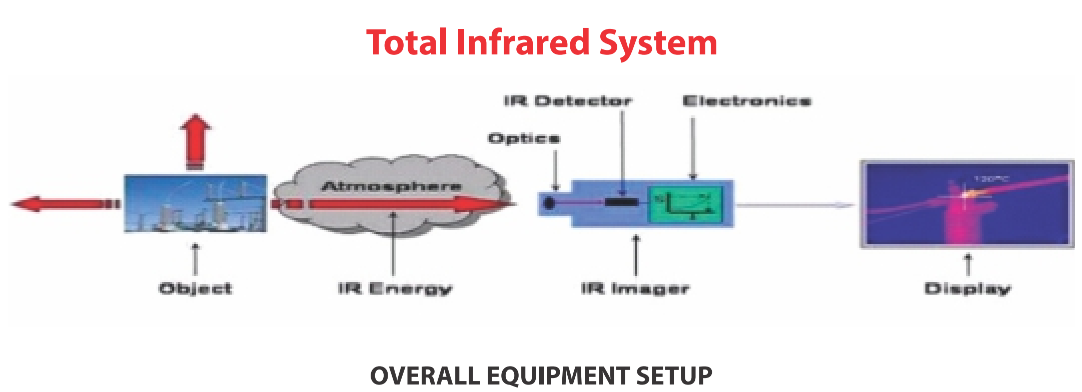

Fig 1: principle of thermography

2. PASSIVE THERMOGRAPHY

Inspected part are at a higher or lower temperature than the background.

It has two parts,

• The Infrared Camera or Detector

• A standard PC or laptop computer

APPLICATIONS OF THERMAL IMAGING IN MEDICINE

Thermography provides an advantage of real time two-dimensional temperature assessment. With modern technology, a single image may contain several thousands of temperature points, recorded in a fraction of a second. The human body is homoeothermic. The body core is relatively stable in temperature, but the shell of the body forms part of the regulatory process. Humanskin behaves as an almost blackbody with an emissivity of 0.96–0.98. (Fig.2)

Inflammatory arthritis

Physicians, from earlier times used cardinal signs of inflammation, i.e. pain, swelling, heat, redness and loss of function. An acutely inflamed joint produces an increase in heat and can be readily detected by touch. Thus increase and decrease in temperature can have a direct expression of reduction or exacerbation of inflammation. Therefore variations due to treatment, whether pharmaceutical, surgical or physical can be objectively measured. Infrared imaging was also shown to be a powerful tool for the clinical testing of these drugs, using temperature changes in the affected joints as an objective marker. The technique had been successfully used on animal models of inflammation, and effectively showed that optimal dose response curves could be obtained from temperature changes at the experimental animal joints. The process with human patients suffering from acute rheumatoid arthritis was adapted, to includea

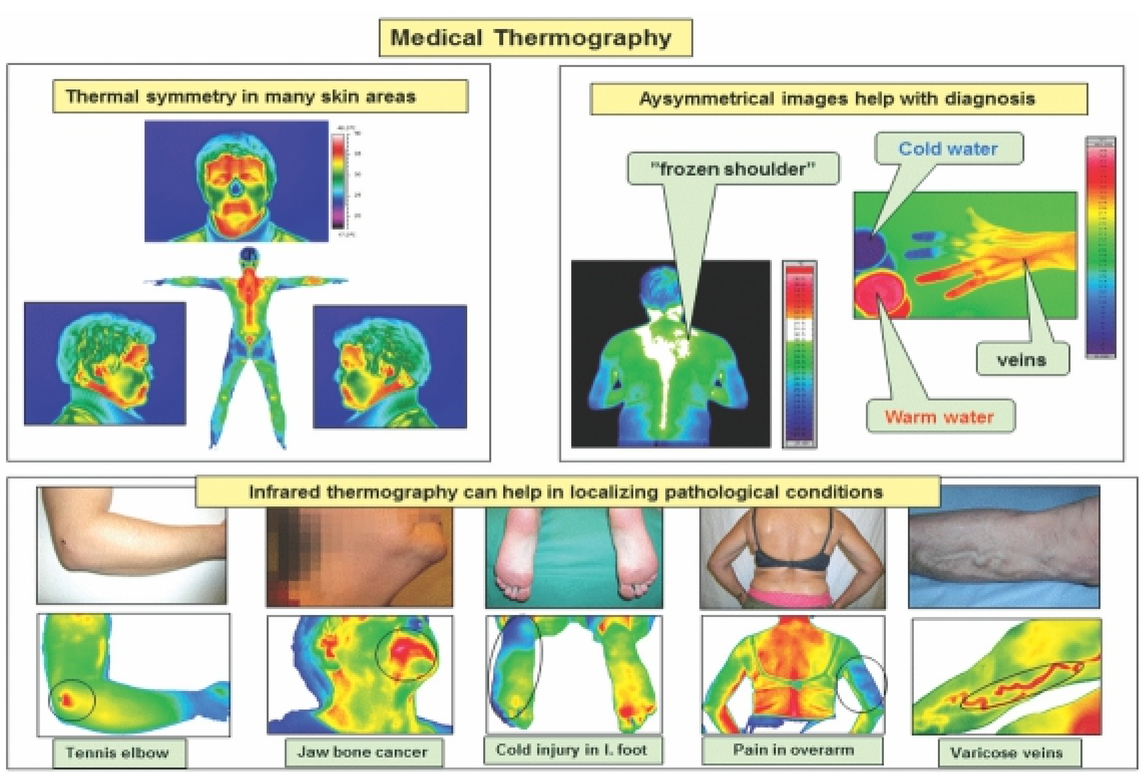

Fig 2: Various applications of medical thermography

washout period from previous medication. However, temperature measurements over joints have not generally been considered for inclusion in core sets of outcome measurements for the assessment of response to newer biological agents for inflammatory arthritis. Recently, a pilot study from the United States found a high coincidence between high temperature and swelling of finger joints detected by three-dimensional images. A heat distribution index was created by the authors, which had a diagnostic specificity of 100% and sensitivity of 67% for arthritic swelling (Spalding et al 2008).

Soft tissue rheumatism

Most important source of increased metabolic heat is muscle action. Therefore, contracting muscles contribute to the temperature distribution at the body's surface of athletes (Tauchmannova etal1993, Smithetal1986).Pathological conditions such as muscle spasms or myofascial trigger points may become visible as regions of increased temperature (Fischer and Chang 1986).. However, long lasting injuries and scars appear as hypothermic areas caused as a result of reduced muscle contraction, and therefore reduced heat production. Decreased temperature have been also found adjacent to peripheral joints with reduced range of motion due to pain or inflammation(Ammer 1995a).

Tennis elbow

Painful muscle insertion of the extensor muscles at the elbow is associated with hot areas on a thermogram (Binder et al 1983)[9]. It can detect persistent tendon insertion problems of the elbow region in a similar way as isotope bone scanning (Thomas and Savage 1989). Hot spots at the elbow have been described as having a high association with a low threshold for pain on pressure (Ammer 1995b)[8]. Such hot areas have been sucessfully used as outcome measure for monitoring treatment (Devereaux et al 1985, Meknas et al 2008)[10]. Bilateral hot spots at the elbows is a common finding in patients suffering from fibromyalgia, (Ammer et al 1995).

Osteoarthritis

Varju et al compared thermograms with radiographs from patients with hand osteoarthritis (Varju et al 2004)[11]. Increased temperatures associated with even slight degenerative changes (Kellgren-Lawrence grade 1) and low temperatures in more severe disease (Kellgren-Lawrence grades 2-4)was reported. However, the age of the patient in the different grades of severity of osteoarthritis has not reported, and the decrease in surface temperature over more severely affected joints could have been caused by concomitant diseases. Mayr reported that after knee surgery the time required to achieve normal temperature is at minimum 120 days, but the knee joints couldnt achieve thermal symmetry even after 10 months in some patients (Mayr 1995)[12]. An Italian study observed identical anterior knee temperature 90days after total knee replacement (Glehretal 2011).

Fibromyalgia

There are two terms used by physicians in the examination of muscular pain: trigger points (main feature of the myofascial pain syndrome) and tender points (important for the diagnosis of fibromyalgia). These may give a similar image on the thermogram. Patients suffering from fibromyalgia may present with a high number of hot spots in typical regions of the body. More hotspots are found in Fibromyalgia and least in healthy patients. Therefore it was concluded that more than seven hot spots could be predictive for tenderness in 11 or more of 18 specific sites (Ammer 2008c).

Complex regional pain syndrome

A temperature difference between the affected and the non-affected limb equal or greater than one ^{0}C is one of the diagnostic criteria of the complex regional pain syndrome (CRPS) (Wilsonet al 1996). A study was conducted by Ammerin patients treated conservatively with a plaster cast after radius fracture (Ammer 1991a). Thermal image recordings were taken within 2 h after plaster removal and after 1 week. An x-ray image of both hands was taken after the second thermogram. After plaster removal the mean temperature difference between the affected and unaffected hand was 0.6 ^{0}C and 0.63 ^{0}C 1 week later. Slight bone changes suspected of algodystropy were found in some 50% of 41 radiographs. It was found that the temperature difference decrease during successful therapeutic intervention and the temperature change was paralleled by reduction of pain and swelling and the resolution of radiological changes (Ammer 1991b).

Peripheral circulation

In some of circulatory disturbances conditions such as Raynaud's phenomenon, or hand arm vibration syndrome, thermal imaging can assess damage to small blood vessels from exposure to vibrating machinery and the effect of local blood circulation on skin temperature. This is found after the contact with a vibrating surface at a known frequency or exposure of hands to a temperature stimulus. Most commonly, a number of studies have reported the value of the thermal challenge test, particularly for quantifying the 'vasospastic' reaction found in Raynaud's phenomenon (Ammer 2009). After a baseline thermogram of both hands the hands are protected by plastic gloves and immersed in a water bath for 1 min (typically 18-20 ^{0}C). The thermal recovery is then monitored. In healthy subjects, this can lead to are active hyperaemia of the fingers, while in Raynaud's sufferers there is a slow protracted recovery of more than 15 min to baseline. The above test are applied in various studies and trials of vasodilator treatments. In most cases, some improvements can be measured, but ultimately normal recovery is rarely achieved.

Fever screening

Currently thermal imaging is used for fever screening. After the SARS (severe acute respiratory syndrome) outbreak in South East Asia, thermal imaging systems had been installed to screen travellers at the time of pandemic. In the current situation of covid-19 pandemic the thermal imaging systems may have a future scope.

Malignant diseases

Many of the early investigations with thermal imaging some 50years ago were entirely focused on the potential of this technique to become a useful tool in breast cancer diagnostics. For many of the reasons cited above, large expensive and unstable camera systems, before even computing and image processing was available, made this a difficult and unreliable tool. There were undoubtedly some interesting 'positive' findings, but the arrival of both mammography and ultrasound effectively made thermal imaging of less interest.

Other applications

Thermal imaging is now increasingly used for imaging different physiological reactions induced by non-drug treatments such as massage (Bonnettetal 2006[13], Seftonetal 2010, Holey et al 2011, Wuet al 2009) or manual therapy (Mori et al 2004, Royet al 2010). Temperature distributed over the skin during and after physical exercise has been reported (Zontak et al 1998, Ferreira et al 2008, Merlaet al 2010). The effects of thermo therapy were recorded with help of thermal imaging (Ammer 2004)[14] and also water filtered infrared irradiation were monitored by thermography (Mercer et al 2008[15]. Notter et al 2011)[16]. Various modalities for cryotherapy have been evaluated with thermal imaging (Selfeetal 2009, Schnelland Zaspel 2008). Recent studies have also used thermography as an outcome measure in trials investigating low level laser treatment for myofascial pain (Hakg¨uder et al 2003)[17] or knee osteoarthritis.

CONCLUSION

Infra red thermography is a fast, safe and clean technology that is used in a wide variety of applications.This paper focused on two applications: measurement of temperature and non-destructive testing. The principles behind these two fields have been reviewed. This background information is provided to help the dissemination of these technologies and to assist beginners in a better understanding of the subject. Moreover, recent work on these topics has been reviewed and discussed. In a very short period of time infrared thermography has experienced a great evolution. Important improvements were achieved in different fields. However, there are limitations to be considered. Infrared thermography is highly dependent on the sensor selection and the experimental setup. It may be affected by the instrument and by the environment. These problems can be minimized, but only with adequate setup and testing procedures, which mostly depend on the operator's skill. Infrared thermography is a mature technique for non-destructive testing. Recent advances in this field allow this technology to detect many types of defects. However, the presence of a visible thermal contrast can only help to detect a defect using infrared thermography. Future sensors with improved sensibility are required to improve the general applicability of this technique. Further work is also required in signal and image processing on the acquired infrared thermal images in order to enhance the detection, to simplify the interpretation of the results and to reduce human interference. Nowadays, use of infrared sensors limited. This is partially due to the cost and due to lack of adequate training. But the scope of infrared thermography in the near future is unpredictable.

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