Infrared Thermography on Osteoarthritis-A Review

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Abstract--
Objective: To conduct a review on the diagnosis of osteoarthritis (OA) using Infrared Thermography (IRT), intended to provide physiological information of the affected joint.

Method: An extensive article search is performed based on the term “Osteoarthritis” in combination with “Infrared Thermography”, “Imaging”, and “Radiography”, to extract relevant studies. This review focuses on technical requirements and usefulness of IRT in diagnosing Osteoarthritis, with a special focus on skin surface temperature elevation around affected joint area correlated with severity of OA based on radiographic findings. The literature review is carried out based on funnel approach. Out of 55 articles only 28 were selected on basis of Level 2 and 3 of the paradigm funnel approach

Result: In future, infrared thermography in OA offers an exciting potential in understanding the process of disease across all the joints so that effective and preventive interventions are developed.

Conclusion: None of the screening tool provides excellent predictability when used alone but a combination of the available screening tools along with thermography can increase both sensitivity and specificity of the available diagnosis method.

Keywords- Osteoarthritis, Infrared Thermography, Surface Skin Temperature, Radiography

I. INTRODUCTION

Thermography is a non-contact and non-invasive skin surface temperature screening method that is quick, economic and does not impose any pain on the patient. It is a relatively straightforward non-radiographic imaging approach that detects the temperature variation on the human skin surface. Knee and hip joint is more likely to be affected from OA as it bears most of our body weight [1].

Osteoarthritis is considered to be a progressive form of arthritis characterized by joint cartilage breakdown. Osteoarthritis abbreviated as OA is also known as degenerative joint disease. Osteoarthritis will cause pain in the joints with activity. Osteoarthritis is common in people over 60 years of age, but it can be even found to effect younger people when they have a history of joint injury. The possibility osteoarthritis (OA) diagnosis increases with age, over 30% to 50% of adults with age of above 65 years are affected from OA [2].

In musculoskeletal trauma, the application of IRT records long history. Albert et al. [3] made an early effort to use infrared thermography for pain assessment.

But later, many research studies approved or denied this new technique. Medical use of infrared thermography was challenged in many research works because it provided low diagnostic specificity and poor stability for localising the values. Because of availability of high resolution IR camera and effective calculation methods, infrared thermography is again gaining attention in recent research works especially in tumour detection. The infrared thermography gives information about the skin surface temperature which can be related to the complex thermoregulatory process. Infrared thermography evaluates the thermal aspect of the affected OA by measuring skin temperature over inflamed joints, which cannot be shown by present conventional methods.

II. INFRARED THERMOGRAPHY ON OSTEOARTHRITIS

Infrared thermography (IRT) is a non-contact device used to measure and process the thermal information form the acquired IR image [4]. The principle of IRT is based on capturing the infrared radiation which is a form of electromagnetic radiation emitted from an object. The wavelength of infrared radiation is longer than that of visible light. IR radiation is emitted from any object with temperature above absolute zero [5]. IR radiations are not visible to human eyes and thus this measurement can be acquired and processed using an infrared measuring instrument.

IRT in medical application have many advantages over other screening technologies [7]:

1. IRT is a non-contact thermometer. As it is a non-invasive technique, patient will not be affected in any means.

2. IRT yields 2D images where each pixel represents the temperature value, from which different region of interest can be studied

3. IRT is dynamic imaging technique enabling real time acquisition of stationary and fast moving target object.

4. Unlike X-Ray which is commonly used for detecting joint structural changes, IRT is a non-radiating imaging technique that makes it suitable for frequent and prolonged use.

IRT is advantageous in the healthcare, as readings obtained with this non-contact technique are accurate. IRT is a non-invasive technique which means that it is a painless procedure and this type of measurements will be of great importance in the medical field.
Because the instrument measurement obtained from IRT is a non-contact technique, the accuracy of the measurement is not affected and enables the measurement to be acquired remotely. In alternative methods, the measurements may be corrupted because the sensors are in contact with the subjects. IRT not only measures the temperature around affected area, but variables such as stress can also be analysed using the thermal information from the IR image [8]. In many medical applications IRT can be considered as an effective tool due to its advantages as discussed previously [9]. IRT being low cost diagnosis tool can be used to scan athletes in sports medicine to analyse their physical conditions [10]. However, IRT do have drawbacks. Today’s advance technologies have produced much fast and affordable hardware, but still an infrared camera used for IRT is an expensive instrument. Though these affordable cameras have good spatial resolution, accuracy of the measurement obtained from these cameras is very low which makes them unsuitable for certain applications. Interpretation of the thermal images requires specific training. IRT must be performed in a controlled environment because the sensitive IR camera will also consider the emissions from a secondary IR source that leads to inaccurate temperature measurement.

A. Measures to be taken before IRT is performed in clinical practice

In clinical practice, emissivity will not be an issue as the emissivity value for skin temperature is precisely known; but there are other variables such as the surrounding temperature, humidity or airflow greatly influence the skin surface temperature measurement [11,12]. The place where IRT is performed must be a room with controlled environment that are free from other secondary sources that emit infrared radiations. The subjects participating in thermography require rest without much physical activity in a comfortable position so that their body temperature attains equilibrium. Before IRT, subjects will have to follow set rules, such as not be exposed in sun for long time and must not apply any lotions or creams on the target region where the IRT is to be performed. Participants must not consume alcohol or caffeine for at least 24 hours prior the procedure starts. Many different applications are found where the above procedures are considered for data acquisition using infrared camera [13].

B. Temperature measurement in IRT

Varju et al made comparison of radiographs with thermal images from patients with hand OA [14]. They measured finger joint temperature that ranged between 21.42°C and 37.17°C was recorded in an controlled environment with constant temperature of 21°C.

In conclusion they reported that increased temperature is associated with early degenerative joint structure change (KL grade 1) and low temperatures were reported in more severe degeneration (KL grades 2 to 4). They question the temperature measurement accuracy because studies in arthritis that compared radiographs and thermal images were published in 2002 from Japan [15] and in 2010 from the United States [16], and found that increased temperature is associated with severe radiographic degeneration in osteoarthritic knees.

Nikolaet al. [17] showed that the mean value of the skin surface temperature of the dorsal side of the hand observed in normal subjects was in the range from 25.4°C to 35.1°C, in people who suffered from OA in the range from 25.6°C to 35.4°C, and in subjects with rheumatoid arthritis in the range from 24.8°C to 35.0°C. At the same time, mean skin surface temperature of the ventral side in all groups was a bit higher and in the healthy subject it was in the range from 24.8°C to 35.5°C, in subjects with osteoarthritis from 25.5°C to 35.6°C, and in subjects with rheumatoid arthritis from 24.8°C to 36.5°C.

The thermal images have been used to examine anterior knee for the detection of knee OA [18-20]. Bacon et al. [21] showed that the disease activity can be measured by considering the mean surface skin temperature of the target region. The intra-articular temperature in patients with rheumatoid arthritis was measured by Horvath and Hollander [22] to assess the acuteness of inflammation. Ben Alyahu et al. [23] investigated on the clinical utility of IRT for detecting patellofemoral pain syndrome in patients which showed that the incidence of patellar thermal asymmetry was found to be statistically significant when analysed with chi-square test.

C. Feature extraction for analysis of thermal images

An infrared camera produces a thermal image with each pixel a temperature measure calculated from the captured emissivity. One of the problems of using IRT in medical applications is to arrive at a single temperature value measurement for the region of interest. However, for clinical practice a single temperature measure of the target region is necessary. A procedure to combine all the information available to get a single temperature measure was introduced by Ludwig et al [24]. They analyzed different methods for obtaining single temperature value: $T_{\text{max}}$ calculated average temperature from all the pixels in the area selected; $T_{\text{avg}}$ calculates an average of the temperature pixels in the area of 5 x 5 around the pixel that has the maximum temperature; and $T_{\text{tot}}$ calculates an average pixel temperature value in the entire region of study. Authors conclude that though all the three methods give similar results, $T_{\text{max}}$ is considered as it is helpful for thermal image analysis in real time.
There are works that focuses on region of interest (ROI) extraction from the thermal image to determine the temperature of the target object. In most of the applications, infrared images contain information about the target object along with the information about their surroundings.

Figure 1 2cm anatomic marker places at patellar during IRT (left). The black circle is the marker region that has blocked temperature radiation (right) [16]

Denoble et al [16] to identify ROI a 2 cm anatomic marker (silver sticker) is applied patellar centre during IRT procedure (Figure 1 left) that blocks temperature radiation from that region i.e. the black circle in thermal image enabling the easy recognition of patellar region (shown in Figure 1 right). The patellar centre identified can be used to quantify mean temperatures for the following regions of interest: P-patellar; M-medial; L-lateral; LM-lower medial; LL-lower lateral. These regions are represented in figure 1 (left).

Herry and Frize [25] proposed an automated method for identification of ROI using a method between Uematsu’s (partial) technique and Goodman’s (complete) technique and select the ROI based on the shape and intensity distribution in the thermal image. It is an automated method. One more paper [26] showed that segmentation of the thermal image by using the fuzzy c means algorithm produced the region of interest i.e. the affected area of hand osteoarthritis as shown in Figure 2. Statistical measure extracted from Thermal image with artificial neural network provides an alternative method to existing technology for auto-detection of the Arthritis. The system is implemented in [27] provides reliable results.

Figure 2 Input Thermal Image (top) is segmented using fuzzy c means algorithm to get the region of interest (bottom) [26]

A semi-automated diagnostic method based on patellar-centring was developed in [28]. An effective knee feature extraction method based on patellar-centring was proposed in this paper. The features extracted were fed to an SVM classifier for automatic detection of normal and abnormal knee OA cases. Results obtained had an accuracy of 85.49% with 85.72% sensitivity and 85.51% specificity. The proposed system in this paper is suitable for knee OA screening or physical examination.

III. CONCLUSION

Infrared image capture and analysis is an outstanding technology that allows non-contact, non-radiating, non-invasive investigation of biological systems, both in preclinical research settings and in the clinical assessment of patients. This paper has reviewed on temperature measurement and methods for extracting features from infrared images of joint affected from osteoarthritis. Many studies [1,15,16,20,21, and 26] showed the correlation of the radiographic severity of osteoarthritis with the skin surface temperature.
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IRT can provide physiological information but cannot define cause and local anatomy of the disease. The interpretation is limited as the individual variability is combined with the complex character of thermoregulation. The lack of specificity makes it necessary to combine these measurements with other, more structural modalities (X-ray, Computed Tomography), rather than using it as a replacement. IRT cannot substitute clinical examination but can enhance it.

Competing Interests
All authors declare that there is no conflict of interest.

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