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Analysis of Breast Thermography Based on Inside Thermal Estimation

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Abstract—Breast cancer has been known as the most common type of cancer among women. Because of thermal information reflecting the physiology and pathological state of human body, thermal diagnostics has been used for early breast cancer detection and risk prediction. The thermal information at skin surface can be easily obtained and helpful to understand the breast disease process that goes with thermal abnormalities. From the infrared thermal images, the method of inside thermal estimation (ITE) investigates the alterations from the normal temperature to establish a correlation between skin thermal information and breast cancer. Based on ITE, a large number of breast infrared images are analyzed in this paper. Its reasonability was validated.

Keywords-breast cancer; thermal information; inside thermal estimation; infrared thermal images

1. Introduction

Temperature of body surface is determined by the blood circulation underneath the skin, local metabolism, and heat exchange between the skin and its environment [1] [2]. Abnormalities in surface temperature distribution have been recognized as a sign of disease, reflecting the physiological and pathological disorders of human body [3]. Clinically the temperature distribution of human body can be captured by infrared camera, and some useful information imbedded in infrared images can be extracted to identify the inner abnormalities related to diseases.

The infrared thermal images obtain skin temperature distribution through detecting thermal radiation emanating from the human body surface. In contrast to traditional non-invasive thermometry, such as MRI, ultrasound and microwave, thermography is an attractive technology with lower cost and higher sensitivity. In clinical practice, thermography is widely used in the screening for breast cancer, extra-cranial vessel disease and vascular disease of the lower extremities [4].

However, thermography has its own disadvantages. Its application is limited if only the skin temperature can be obtained. Thermography shifting from phenomenology to pathophysiology [5], the inherent correlation between skin temperature and the inner abnormality should be established. Based on the numerical simulation of biological heat transfer process, by investigating the relationship between skin temperature and the inner abnormality, ITE can estimate the location of the inner abnormality.

2. Method

With a better understanding of heat transfer process of the tissue, the thermal analysis method of ITE can deduce the information related to the inner abnormality from the infrared images of skin surface image.

2.1. Numerical algorithm of ITE

The process of heat transfer in human body can be described with Pennes equation, which yields a better description of the heat transfer where the vessels diameters are greater than 500 microns [6].

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$$\rho c\frac{\partial T}{\partial t}=\nabla\bullet(k\nabla T)+Q_b+Q_m \tag{1}$$

where T is the local temperature, ∇ is the Laplace operator, ρ, c, k are the tissue density, specific heat and heat conductivity respectively. Q_b , Q_m are the Pennes perfusion term and the metabolic production separately. Considering a more simple condition, the 2-D heat transfer process in steady state in isotropy tissue with properties independent with temperature, and taking the blood perfusion effect and metabolic heat product as a integrated heat source Q, the pennes equation can be written as:

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}=\frac{-Q}{K} \tag{2}$$

The boundary condition for the heat transfer occurring at skin surface is:

$$-k\frac{\partial T}{\partial n}=h_{con}^{'}(T-T_e) \tag{3}$$

where $h_{con}^{'}$ is the equivalent coefficient of heat exchange including convection and radiation. T_e is the environment temperature.

The above equations can be solved with finite element method (FEM), which is a powerful method for solving partial difference in biological heat transfer problems with complicated boundaries. With numerical simulation, the thermal behavior at skin surface with different depth is investigated, and therefore the relationship between skin thermography and inner abnormality can be established [7], which is the theoretic foundation of ITE.

2.2. Application of ITE in thermographic analysis

A thermographic analysis system based on ITE is designed as Fig. 1.

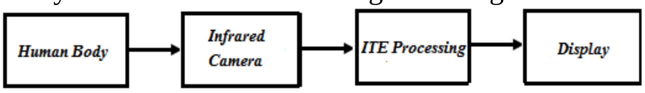

Figure 1. The scheme of the thermographic analysis system

Firstly the skin thermal information can be captured by infrared camera. Then apply ITE to estimate the location of the inner abnormality. The results are shown for diagnosis. Given its temperature, the depth of the inner abnormality is regarded as one of the important parameters to induce the thermal alteration at skin surface. To reveal the location of the inner abnormality clearly, the thermal distribution maps of human body are shown layer by layer from surface to the inner. With a constant increment in depth, the location of the inner abnormality can be represented with its layer number.

3. Results and Discussion

We collected the breast thermographic data from over 1600 females, including females with or without breast disease both. Every participant was asked to take 3 infrared images, one for the both breasts, the other two for right and left breast respectively.

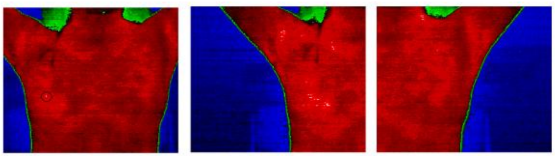

Figure 2. The original infrared images of a participant with tumors in both sides

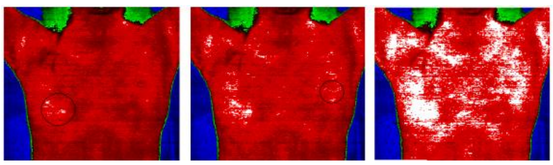

Figure 3. The reconstructed images of the same participant with different depth

Three original infrared images of a female at 29 after menstruate are shown in Fig. 2. This participant is a patient clinically diagnosed with breast tumor in both sides. The thermal information of her breast has been recorded in the infrared images, but the subtle inner abnormality could not be recognized. From the images, we fail to find out the tumor area.

After ITE processing, we obtain the reconstructed thermal images. In Fig. 3, the different image reveal the changing temperature distribution with increasing depth. From left to right, they are of 6th layer, 10th layer and 19th layer separately. With the increasing value of depth, the hidden abnormalities appear much clearly. The local area marked with circle line indicates the location of breast tumor, which matches to the clinical diagnosis.

Furthermore, we also apply ITE to the thermographic analysis of different kinds of females. Based on the related results, age and the disease type are highly associated with the thermal distribution. And the thermal distribution pattern is also much sensitive to participant's own circadian rhythm.

4. Conclusion

As a non-invasive method, ITE is a kind of attractive diagnostic technique with relatively lower cost and higher sensitivity. Based on the relationship between surface thermal distribution and inner abnormality, ITE can deduce the information of the inner abnormality and provide useful guidance for physicians to diagnose. In this paper, ITE was applied to analyze the breast thermography. The results validate its reasonability

5. Acknowledgment

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6. References

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