EARLY CANCER DIAGNOSIS BY CONDUCTIVE OR RADIATIVE BIOHEAT EVALUATION

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Keywords: Bioheat, thermal imaging, cancer, radiation or conductive heat, image processing

Abstract: *The heat is one of the most important parameters of living beings. The tissues heat, generated at normal or diseases states, is lost to environment through several mechanisms: radiation, conduction, convection, evaporation, etc. Skin temperature is not the same on the entire body and a thermal body signature can be got. The temperature of neoplasic tissue is different up to 1.5* ^{0}C *than the healthy tissue as a result of the specific metabolic rate. The infrared camera images show the heat transferred by radiation very quickly. A lot of factors disturb the conversion temperature-pixel intensity. A very sensitive sensor, a video camera showing its spatial position and a special computer fusion program were used for early cancer diagnosis. By using the high resolution maps, the diagnosis for about 78.4% of patients with thyroid cancer, and more than 89.6% from patients with breast cancer were right.*

1. INTRODUCTION

Humans and animals in general, are usually in a thermal steady state with respect to their surroundings. The heat is one of the most important parameters of living beings. All our common activities rely on energy cost. Sleeping, for instance, needs 35 cal/m2 hr, and running 600 cal/m2 hr [1]. Approximately 80% of these costs are given by waste heat. Thermal physiology describes all body functions related to thermal energy given to or removed from a living body. Therefore, the body needs a temperature regulation, which keeps the temperature on a constant level, about 37 ^{0}C. There is equilibrium between outside of body and skin temperature. The sympathetic nerve fibers are involved in temperature regulation, and this is the autonomic nerve system function, it is a non-voluntary control. As a result of different situations, the core temperature may be increase (hyperthermia) or decrease (hypothermia). The skin temperature and the core temperature determine the regulation process [2], [3]. The temperature distribution on the human skin gives a thermal image, a thermal pattern of the body, with highly symmetrically distributed related to a symmetry axis situated in the median plane of the human body. In many situations, this pattern is not symmetric and hyperthermic or hypothermic areas appear. There is a strong link between these thermographic changes and diseases. Hyperthermic or hypothermic skin areas may be caused by increased or decrease blood flow, tumors, inflammation process, etc. Tumor vascularity particularly played a fundamental role in promoting cancer growth, invasion, and metastasis [1], [4]. Solid tumors rely on blood vessels to obtain necessary nutrients and oxygen [5]. New vessels also offer path way for tumor expansion; therefore, increase the opportunity for tumor cells to enter the blood or lymph circulation. Rapid and noninvasive imaging techniques may be a better alternative for assessing tumor vascularity. In medical applications, infrared imaging can produce reliable and valid results and it is based on the physics of heat radiation or conduction and the physiology of thermoregulation of the human body.

The final aim of the research is to find some clues in order to get an early cancer diagnosis. As a result of angiogenesis process, the skin projection of the certain tumors modifies the local area temperature. The temperature can be measured by many means: contact thermocouples, non-contact infrared thermocouples, resistance temperature detectors, thermistors, liquid crystal sensors, and microbolometers. All of them have advantages and disadvantages concerning to this medical application. The thermistor sensor is the cheapest and IR camera with microbolometres is the most expensive sensor. The problem, we are looking for, is in what way the measurement results by the two sensors are the same. The heat, generated in the region of interest, is spreaded through several mechanisms: radiation, conduction, convection, evaporation, breathing, etc. The contact thermistor sensor uses the conduction component of this mechanism, and IR camera, radiation one. Some aspects have to be taking in consideration. The thermistor sensor measures the heat with an infinite range of wavelengths, from theoretical point of view, and IR camera on 8-14 microns only. Human skin temperature is the product of heat dissipated from the vessels and organs within the body, and the effect of the environmental factors on heat loss or gain. There are a number of further influences which are controllable, such as cosmetics, alcohol intake or smoking. The radiated heat depends on a lot of parameters: skin emissivity, environment between cameras and the investigated area, other heat sources, etc. So, do the results reflect the same situation when the measurements are made by thermistor or IR camera?

2. MATERIALS AND METHODS

The heat transfer by conduction from skin gives information more appropriate to reality and can be used to early cancer diagnosis, but up to now, only point temperature measurement has done. We used a very sensitive sensor, 0.04 ^{0}C temperature resolution, and a video camera showing the sensor spatial position. A special computer program was created for sensor and video camera data fusion. The investigated surface and a red circle showing the sensor position are displayed. When the successive temperatures values are appropriated, the circle becomes green. The temperature sensor is moved on the region of interest and a green patch appears. A computer program using the spatial adaptive spline functions assures 0.5 mm spatial resolution. The IR camera has about 1-3 mm spatial resolution and 0.10C as a temperature resolution of one microbolometer from the focal plane array.

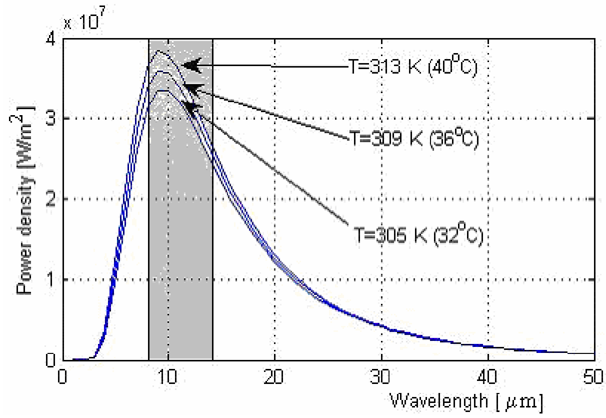

Fig. 1 The radiated energy versus medical temperature

From spectral point of view, the thermistor sensor covers almost entire frequencies range but IR camera 8-14 microns only. The amount of radiation energy Eo, emitted by a blackbody at an absolute temperature T, per unit time, per unit area of surface, per unit wavelength λ, is given by Planck's law, [5]:

$$E_\lambda = \varepsilon_\lambda E_{\lambda o} = \frac{\varepsilon_\lambda c_1}{\lambda^5\left[\exp\left(\frac{c_2}{\lambda T}\right)-1\right]} \quad (1)$$

On Fig. 1 is shown radiated energy for biomedical range, 32 ^{0}C – 40 ^{0}C. For entire temperature range, the blackbody emissive power is:

$$E_o = \int_0^\infty E_{\lambda o} d\lambda = \sigma T^4 \quad (2)$$

IR camera operates on a part of this spectrum, so we need to determine the fraction f12 of blackbody emissive power between two wavelengths by integration of Equation (1) and division by Equation (2):

$$f_{12} = \frac{\int_{\lambda_1}^{\lambda_2} \frac{c_1}{\lambda^5\left[\exp\left(\frac{c_2}{\lambda T}\right)-1\right]} d\lambda}{sT^4} \quad (3)$$

The fraction of blackbody emissive power on 8-14 microns band is about 6.5%, and this thing means the thermistor sensor gives more information about temperature. Its main disadvantage is concerning to large rise time, more than 2 s, but for our application it doesn't matter because the investigated skin area is at the steady state. In this paper three sensors: video and IR cameras and a 2.5 mm diameter thermistor were used. The air temperature in the room used for thermal imaging was at about 22 °C during the measurement process, [3], [6]. The time required to achieve the adequate values from thermistor was 15 minutes.

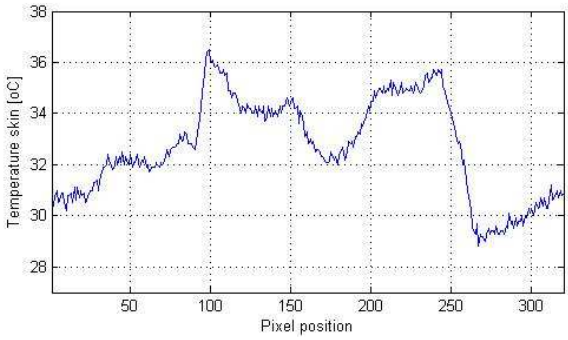

Fig. 3 The output signal from a micobolometer line of an IR camera

3. RESULTS

On the Fig. 2 an infrared image of a patient suffering of thyroid cancer is depicted. The abnormal thyroid aria, a rectangular one, is selected as region of interest, ROI. Most of the temperature pixels show values about 1.5 ^{0}C smaller than neighboring skin surfaces. The ROI temperature is measured by a microbolometer focal plane array. The microbolometers are very sensitive, but don't have the same characteristics. As a result, two adjacent microbolometers give different results, about 0.1^{0}C, for two adjacent regions of the investigation object, and it is seen as a small noise.

On the Fig. 3, the out signal of a horizontal line from the infrared camera is shown. In order to reduce this kind of noise a single sensor was used. The association between the sensor position on the patient skin and its temperature values is obtained by a data fusion computer program

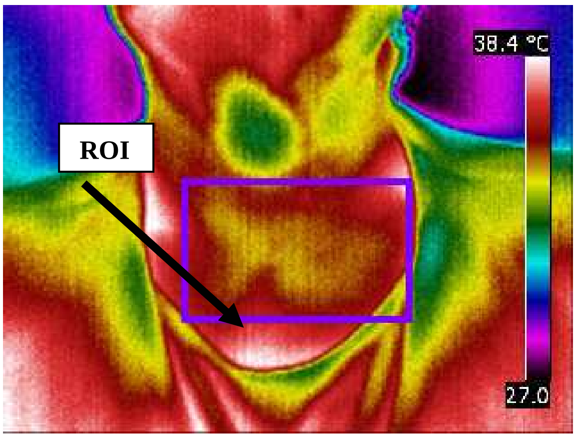

Fig. 2 IR image of a patient with cancer thyroid

The temperature map of ROI, evaluated by the thermistor with 0.04 ^{0}C temperature resolution is shown on Fig. 4. Its spatial position was processed with a computer program using the spatial adaptive spline functions, assuring 0.5 mm as spatial resolution. The neoplasic tissue has a better contour.By looking on Fig. 5, a non-homogenous thyroid aria can be seen. The 3D image shows many small warmer regions on The ROI, as a result nonuniform cell multiplications. The method was tested on patients with thyroid or breast cancer. On the maps of high resolution temperature, the ABCD (asymmetry, border, color, and differential structure) method gives good results, [4]. On the Fig 4 and 5 the strong asymmetry and irregular border can be seen. Other patient, who suffers of thyroid disorders, but no cancer, the two lobes have a regular contour and the same shape.

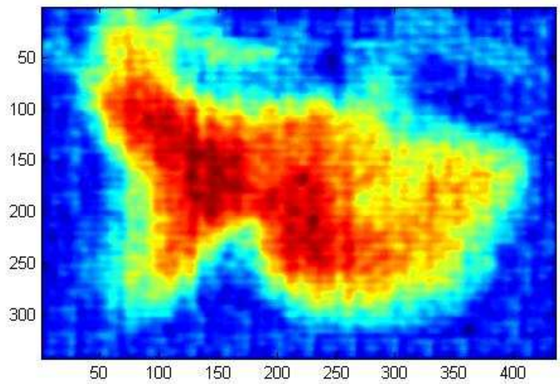

Fig. 4 The temperature map of ROI, the 2D case

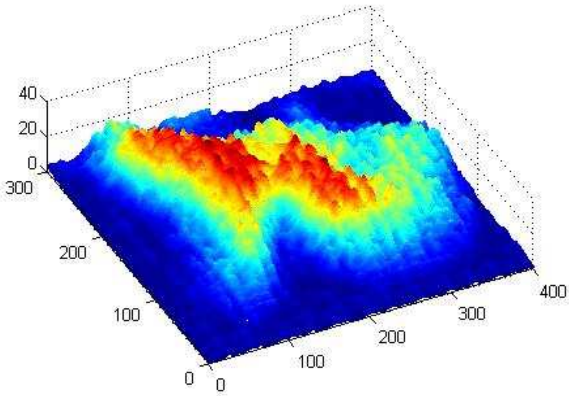

Fig. 5 The temperature map of ROI, the 3D case

A data base, containing 100 temperature maps for healthy people, was created before. As a result of direct comparison, the diagnoses were right for about 78.4% of patients with thyroid cancer and more than 89.6% from patients with breast cancer. On the Fig. 6 is shown an IR image of a patient with thyroid disorders but no cancer

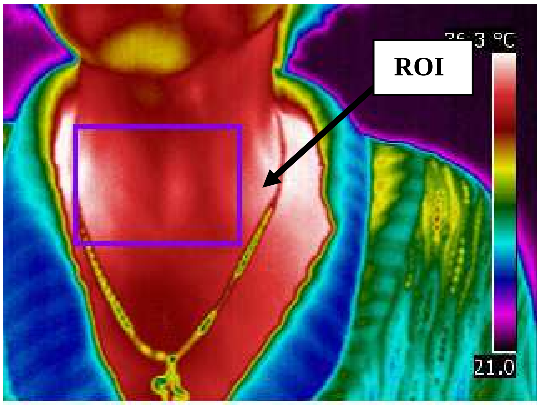

Fig. 6 IR image of a patient with thyroid disorders but no cancer

CONCLUSIONS

A cheaper method for thyroid and breast cancer diagnosis was described. Rapid and noninvasive imaging techniques may be a better alternative for assessing the neoplasic tissue. The sensor, a quick thermistor, measures the radiative heat of the human skin and gives data for a map of ROI with high resolution temperatures. The map is generated by a computer program using data fusion and the spatial adaptive spline functions. The map of high resolution temperatures gives the possibility to do an early diagnosis by looking at the irregular shape of ROI and its structure. The results are pretty good and they can be improved in next future by the fractal analysis.

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