Application of Cold Provocation for Breast Cancer Screening Using IR Thermography

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SUMMARY

A new approach of breast cancer screening using thermovision camera is presented in this paper. The idea is to cool down the healthy and unhealthy breasts or if it's impossible the part of the breasts, and then register a sequence of thermograms in order to get a curve of temperature versus time. We assume that the thermal reaction of the external part of the skin due to the thermoregulation for healthy and unhealthy cases.

Background: A new approach of breast cancer screening using an infrared camera is presented in this paper. Previous studies have shown good results. In this study we are using cold provocation and movement correction in order to enhance the result. We assume that the reaction for cold provocation differs in healthy and cancerous tissue.

Materials and methods: The cancer patients for the study are from a preliminary investigation made in Tampere University hospital. Three out of nine patients examined were suitable for this study. We used a microbolometric uncooled camera IRvox384 thermal camera developed at Technical University of Lodz for medical applications. We cooled the breasts for 15 seconds and then a sequence of 300 images was recorded with the frame rate of 2 frames per second. The total recording time was 150 s.

Results: We found out that the value of time constant is higher in cancerous areas. It means that the reaction of unhealthy tissue for thermal excitation is slower. The temperature is coming back to normal in a longer period of time.

Conclusions: In order to confirm that results are correct and the time constant of breasts with the cancer has a higher value it is necessary to collect more data from patients with diagnosed cancers. We also need to create standard procedures for the imaging sessions so that the results could be repeated as precisely as possible.

1. INTRODUCTION

Breast cancer is the most common cancer among women nowadays (1). It's very important to diagnose the cancer in the early stage, because the chance of being cured is 85% if the tumor is detected and treated before it is over 10 mm in diameter and 10 % if it gets to grow to over 10 mm (2). Very often it is impossible using traditional methods such as mammography, MRI or USG (3). Some of them are invasive and may not be repeated frequently, fig 1.

Traditionally, the screening of breast cancer has been made primarily with mammography and secondarily with magnetic resonance imaging (MRI) and medical ultrasound (USG). The advantages of using mammography are that its specificity is high (up to 99.5 %) and disadvantages that it requires radiation, it is uncomfortable to the patient due to the compression of the breasts, and the fact that the density of the breast tissue affects the sensitivity.

MRI has good sensitivity (up to 100 %) and specificity (up to 95 %), but it is expensive, it takes a lot of time, and it needs to be done with a contrast medium. USG generates a lot of false positives, but it has good specificity in dense breast tissue (4).
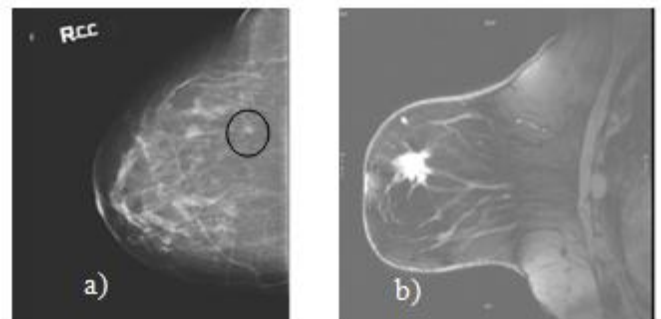

Fig.1 - Imaging of breast cancers using mammography (a) and MRI (b).

Due to these facts, there have been many trials of using infrared thermography (IR) to detect and evaluate the breast cancer. Previous studies have given promising results. Combining IR with

mammography has resulted in good sensitivity (up to 96.5 %) in patients under the age of 50 (5).

The cellular basis of IR imaging is that the metabolic activities of healthy and cancerous tissue differ from each other. The glucose metabolism of a tumor often results in lactate, which causes the cells to need less oxygen but much more glucose than a healthy cell. Due to this, the limiting factor of tumor growth is perfusion, and because of this the tumor stimulates vasculogenesis. The differences in distribution of perfusion are visible in thermography (1).

Most of the previous studies are based on asymmetric distribution of thermal or texture features (signatures) obtained from infrared images (6-9). Typically, the healthy patients have a symmetrical temperature distribution on both breasts, fig. 2 (10, 11).
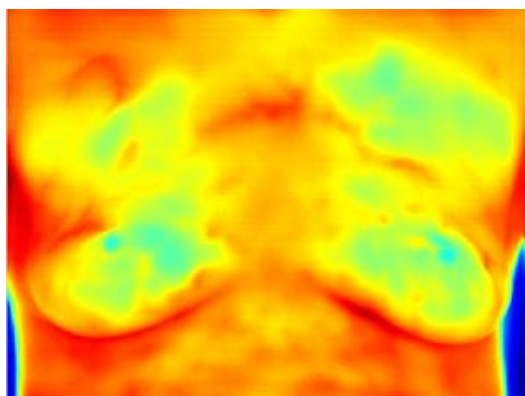

Fig. 2 - Example of healthy woman breasts.

During thermographic measurements it is very important to keep the same environmental conditions. Patients should wait 10-20 minutes before the measurement in the stable and comfortable room temperature and humidity (12-15).

In many cases, the static temperature distribution on the breast skin surface is measured, and typically the cancerous tissue gives higher temperature spots as shown in fig 3 (16). Direct temperature measurement is not very reliable, because temperature of the skin depends on many different factors. This was the main argument to try to correlate the change of the temperature after cooling down the skin with the cancer.
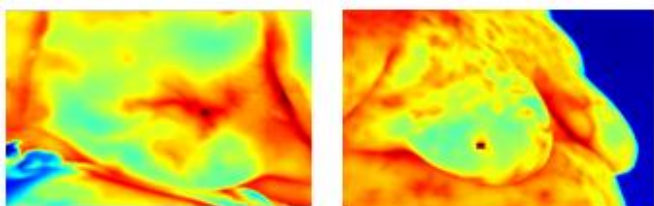

Fig. 3 - Breast cancer thermal images, the cancer position is locate.

2. MATERIALS AND METHODS

It is assumed that cancerous tissue has different thermal time constant. It is due to the different blood perfusion and metabolic rate in contrast to the healthy tissue. We cooled down the skin of the breast of the patients for about 15 seconds using a gel that has been in a fridge for an hour. The initial temperature is not very important as we measure the temperature difference in respect to the initial temperature value just after removing the gel. We used a cooling pad 5 mm thick, which was cooled in refrigerator to the temperature of +4 Celsius. The cooling pad was set right on the skin covering both breasts, and was removed before IR imaging. The measurements were performed for entire breasts, but motion correction was applied to selected ROI's.

The exemplary images for the set of a few hundred recorded for every patient, are presented in fig. 4. Both breasts are cooled to compare the recovery time after cooling. The sequence of 300 images was recorded with the frame rate of 2 frames per second. The total recording time was 150s. The small square region of interest with 16 pixels was chosen, fig. 3 (17, 18).
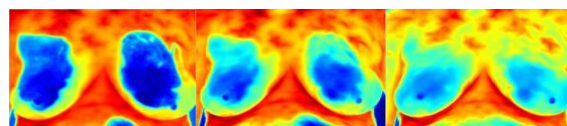

Fig. 4 - Breast cancer thermal images, frames no. 1, 32 and 300, sampling rate 0.5s, total recording time 150s.
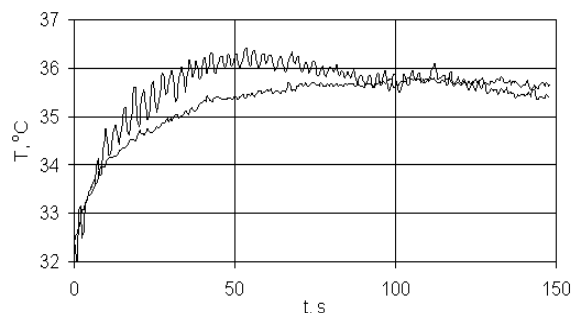

Fig. 5 - Temperature vs. time for a chosen with and without the movement correction.

The breast cancer had been defined with mammography and/or ultrasound, and biopsy before IR-imaging. The breast cancer was localized from mammography images.

The approximation using the exponential function was the next step of the data processing. The example of approximation is presented in fig. 6.
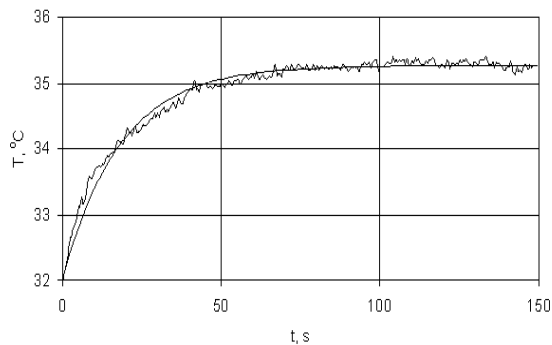
Fig. 6 - Approximation of measured temperature recovery curve with exponential function

We assume the single thermal time constant model of the skin. It denotes that the temperature evolution is time can be expressed by the equation (1).

$$T = T_s \left(1 - e^{\frac{t}{\tau}} \right) \qquad (1)$$

Where T_s is the temperature after full recovery and τ is the thermal time constant describing the heating inertia.

3. RESULTS

The preliminary investigations have been performed as the result of scientific cooperation of Finnish and Polish Technical Universities in Tampere and Lodz. Measurements have been made in Tampere University Hospital using microbolometric uncooled camera IRVox384 thermal camera developed at Technical University of Lodz for medical applications. During the investigation 9 cases of breast cancer were examined. Only 3 of them are reported in this work. The main characteristics of the patients' tumors are summarized in table a below.

Table 1. Characteristics of the tumors

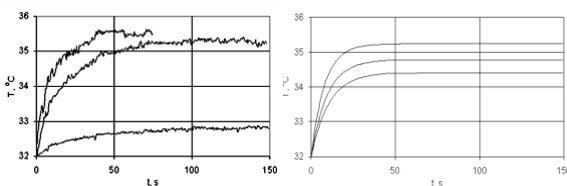| Patient	Tumor type	Tumor size (pathology)	Gradus
B5	Ductal	8 mm	1
B6	Ductal	14 mm	2
B7	Lobular	20 + 10 mm	2

Fig. 7 - Temperature evolution for breast cancer tissue after cold provocation, raw data (left), approximated data (right).

Table 2. Single thermal time constant model parameters for 3 cases of breast cancer

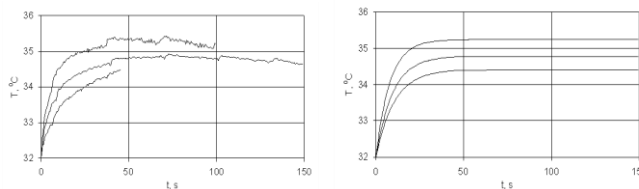| Case	Ts, °C	τ, s
B5	35,5	9,2
B6	35,3	18,1
B7	32,8	27,5

Fig. 8 - Temperature evolution for healthy tissue after cold provocation, raw data (left), approximated data (right)

We can see that the value of time constant is higher in cancerous cases. It means that the reaction of unhealthy tissue for thermal excitation is slower. The temperature is coming back to the normal in a longer period of time. It happens mainly due to the difference of perfusion in healthy and unhealthy tissue.

Table 3 - Single thermal time constant model parameters for 3 cases of healthy tissue

Case	Ts, °C	τ, s
B5	35,2	7,9
B6	34,8	9,4
B7	34,4	10,5

4. CONCLUSIONS

This paper shows preliminary studies of using dynamic thermovision in diagnosis of breast cancers. In order to confirm that results are correct and the time constant of breasts with the cancer has higher value it is necessary to collect more data from patients with diagnosed cancers. The measurement should be done very precisely taking into account environmental condition and other standard procedures in order to repeat the measurement correctly. Next step in our investigation is to extract parameters from the thermal model of human tissue which will suits to the experimental results. Then we will be able to do classification for healthy and unhealthy cases in automatic and quantified way.

REFERENCES:

1. Curado MP. Breast cancer in the world: incidence and mortality. Salud Publica de Mexico 2011; 53(5), 372-384.
2. Diakides NA, Bronzino JD editors. Medical infrared imaging. Boca Raton: CRC Press; 2008.
3. Salhab M., Keith LG, Laguens M, Reeves W, Mokbel K. The potential role of dynamic thermal analysis in breast cancer detection", International Seminars in Surgical Oncology 2006; 3-8.
4. Ravert P, Huffaker C. Breast cancer screening in women: An integrative literature review. J. Am. Acad. Nurse Pract. 2010; 22(12), 668-73.
5. Wishart GC, Campisi M, Boswell M, Chapman D, Shackleton V, Iddles S, et al. The accuracy of digital infrared imaging for breast cancer detection in women undergoing breast biopsy. Eur. J. Surg. Oncol. 2010; 36(6), 535-40.
6. Jakubowska T, Wiecek B, Wysocki M, Drews-Peszynski C, Strzelecki M, Classification of breast thermal images using artificial neural networks, Conf Proc IEEE Eng Med. Biol. Soc. 2004; 2, 1155-8.
7. Więcek M, Strąkowski R, Jakubowska T, Więcek B, Application of thermovision in screening examinations on the example of breast carcinoma, Acta Bio-Optica et Informatica Medica 2010; 16(1), 49-55.
8. Wiecek M, Strakowski R, Jakubowska T, Wiecek B. Software for classification of thermal imaging for medical applications, 9th International Conference on Quantitative InfraRed Thermography, QIRT2008, Inzynieria Biomedyczna 2008; 14(2).
9. Selvarasu N, Nachaippan A, Nandhitha NM. Image Processing Techniques and Neural Networks for Automated Cancer Analysis from Breast Thermographs-A Review, Indian Journal of Computer Science and Engineering 2012; 3(1), 133-137.
10. Ring EFJ, Thermal symmetry of human skin temperature distribution, Thermology International 1999; 9(2), 53-55.
11. Ghayoumi Zadeh H, Abaspur Kazerouni I, Haddadnia J. Distinguish Breast Cancer Based On Thermal Features in Infrared Images, Canadian Journal on Image Processing and Computer Vision 2011; 2(6), 54-58.
12. Ring EFJ, Ammer K. The technique of Infra Red imaging in medicine, Thermology International 2000; 10(1), 7-14.
13. Ring EFJ, Mcevoy H, Jung A, Zuber J, Machin G. New standards for devices used for the measurement of human body temperature, Journal of Medical Engineering & Technology 2010; 34(4), 249–253.
14. Hildebrandt C, Raschne CH, Ammer K. An Overview of Recent Application of Medical Infrared Thermography in Sports Medicine in Austria, Sensors 2010; 10, 4700-4715.
15. Ring EFJ, Ammer K, Jung A, Murawski P, Wiecek B, Zuber J, Zwolenik S, Plassmann P, Jones CD, Jones BF. Standardization of Infrared Imaging, Proceedings of the 26th Annual International Conference of the IEEE EMBS San Francisco, CA, USA,September 1-5, 2004; 1183-1185.
16. Amalu WC, Dabct DC. Nondestructive Testing of the Human Breast: The Validity of Dynamic Stress Testing in Medical Infrared Breast Imaging, Proceedings of the 26th Annual International Conference of the IEEE EMBS San Francisco, CA, USA. September 1-5, 2004; 1174-1177.
17. Mercer J. B., Ring E. F., Fever screening and infrared thermal imaging: concerns and guidelines, Thermology International 2009; 19(3), 67-69.
18. Ammer K., Temperature readings from thermal images are less dependent on the number of pixels of the measurement area than on variation of room temperature, Thermology International 2005; 15(4), 131-133.
19. Strakowska M, Strakowski R, Wiecek B, Strzelecki M. Cross-correlation based movement correction method for biomedical dynamic infrared imaging, QIRT 2012, Naples, 2012.
20. Lewis JP. Fast Template Matching. Vision Interface, Canadian Image Processing and Pattern Recognition Society, Quebec City, 1995; 95, 120-123.

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