Microwave Medical Imaging in a Non-Invasive Breast Cancer Diagnosis System

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Abstract: - The most osteophyl cancer diagnosed amongst women is breast cancer. It's incidence depends on antecedents, on race, on environment, medication and life quality, but it is arising to all ages and it is not forgiving patient ignorance. Easy, non-harmful ways of cancer detection implemented nowadays, became more accessible for all the possible subjects. The main non-invasive methods of breast abnormal area detection are conceived using the optical reflection, and respectively infrared and (our approach) microwave body emission. Noninvasive methods have the advantage of the possibility to be repeated as often as necessary for grow rate or remission survey, essential in diagnosis. Microwave radiometry has been implemented in a complex installation in the Bioengineering Faculty scientific research laboratory, by a multi-disciplinary team.

Key-Words: - Infrared images, microwaves emission, scintigraphy, SPECT, PET, breast cancer detection, magnetic shielded room.

1 Introduction

Early breast cancer detection is essential for increasing patient survival chances. Therefore, periodic examinations are strongly encouraged [1].

Yearly mammograms are recommended starting at age 40, and about every three years for women in their 20's and 30's. with special care at increased risk persons (e.g., family history, genetic tendency, past breast cancer) that should have additional tests (i.e. breast ultrasound and MRI), or more frequent exams.

Using any of the existing techniques [2] such as PET (Positron Emission Tomography), CT (computed X-ray tomography), ultrasound, conventional scintigraphy or MRI (Magnetic Resonance Imaging), medical images of living tissue can be produced.

These techniques [3]÷[8] are powerful and have great advantages, but suffer of important drawbacks, which limit their use.

They are *invasive*, non-portable and discontinuous in their survey, high cost medical monitors.

While new methods arise, a steady, *completely* non-invasive technique is the thermography, already a well-known malignant activity detection method.

2 Human Body Thermo-emission Imaging

Infrared thermal imaging is a non-invasive test of physiology. This is a valuable procedure for alerting the doctor, to changes that can indicate early stage breast disease.

The benefit of digital infrared thermal imaging testing is that it offers the opportunity of breast disease detection, earlier than it has been possible through breast self-examination, doctor examination or mammography.

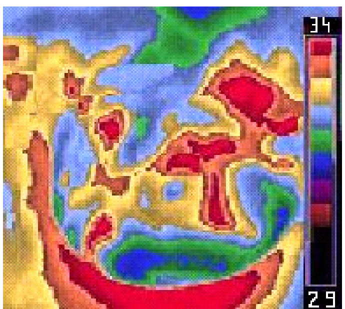


Fig. 1. Abnormal left breast thermography (range 29-34^{o}C)

Digital infrared thermal imaging detects the subtle physiologic changes that accompany breast pathology, whether it is cancer, fibrocystic disease, an infection or a vascular disease. The doctor can then plan a further diagnose and /or MONITOR during and after treatment.
In our laboratory [9], in order to realize experimental thermo-graphic maps, we are using a FLIR ThermaCAM™ B2 Series Infrared Cameras with 0.1 Celsius degrees resolution.
As a practical example, the image presented in Fig. 1. (women, 28 years), highlights the left side marked by large hot and inflamed blood vessels throughout most of the breast. An immediate mammogram was indicated, followed-up by ultrasound in the event that the mammogram was negative.
In this case the mammogram and ultrasound detected a suspicious area in the left breast. A follow-up biopsy confirmed it was cancer.

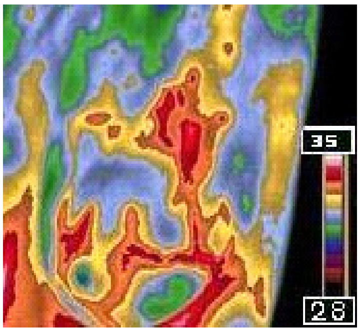


Fig. 2. Abnormal left breast thermography (range 28-35°C)

The left breast is viewed showing the full extent of the hot inflated blood vessels extending throughout the breast, in Fig. 2. The immediate biopsy of the visible area in the left breast came back positive for cancer.

3 Different Breast Cancer Images – Comparison

Fig. 3 is indicating a mammary neoplasm and an important blood flow, highlighted by thermography detection in a black and white pre-processed [20]÷[25] thermography.
Fig. 4. indicates similar results consistent with the previous image, with a mammary neoplasm diagnosed and a suspicious raising non-uniform area detected. This exam belongs to nuclear medicine technique, being an expensive, invasive, and relevant technique of verifying the anatomic functionality of a certain organ or its abnormal parts that constitute the research subsets on the image.

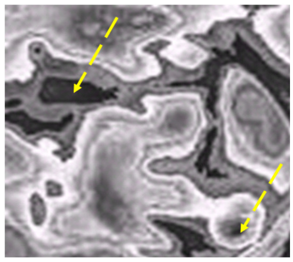


Fig. 3. Black and white transformed thermography

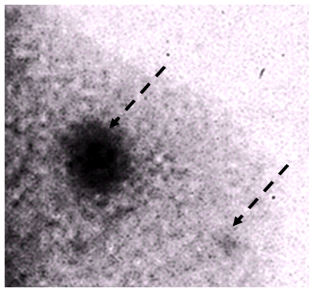


Fig. 4. Mamo-scintigramme with ^{99m}Tc MIBI, confirmation of the anterior presumption

While ultrasounds, magnetic resonance imaging or X-ray methods are already well-known, scintigraphy belonging to nuclear medicine imaging [4]-[9] is a sophisticated, relatively new technique, that highlight the degree of normal functioning, researched in certain body parts, using specific molecules, radioactive tracers that are able to attach (to be uptake) in the target organs.
Certain organs in the body, after the radioactive tracers injection (radionuclide or radioisotope), accumulates them specifically, inside the tissues.
The radioactive tracers help to make the tissues visible on the scanning pictures. Radioactive tracers contain radio nuclides, or atoms that emit energy through radioactive decay to attain a more stable state. Although radioactive decay may occur in one of several forms, the type detected in nuclear medicine is gamma ray emission, sensed by a gamma scintillation camera and expressed as an intensity of radiation called a count.
Once an adequate sample of counts is obtained, this information is relayed to a computer that generates a corresponding image.
Obviously, this is an accurate method, but very expansive and invasive indeed, due both to the special generators (necessary in order to prepare the product to be injected) with a viability of almost two weeks (the radioactivity decrease period) and due to the gamma-camera itself.

4 Our Cancer Non-Invasive Approach

Our research [11]÷[16] focused on infrared and microewave emission detection [17] ÷ [19] in a

protected zone, due to a special constructed shielded room.
Microwaves are emitted (as we all know) by mobil phones and by a lot of electrnic devices we use, as well. In order to make accurate measurements, this shield was conceived, made by special protecting materials.

Fig. 5. Shielded room against the spurious microwave signals for radiometric operations

Each patient is registered with its anamnesis, in order to be possible a further diagnosis, treatment and survey of the grow dynamic in time.
In this shielded camera, for every case, a video, an infrared image and microwave domain measurements are realized, too, with the special dedicated radiometer.
When there are symmetric recordings, there are more possibilities of having a normal situation, while asymmetric radiations generally might be malignant.
Histological exams came to complete the preliminary results.
When using a non-invasive cancer diagnosis technique, the resulting *microwave map* or *thermograph registrations* are better interpreted if they are spatially situated in well measurable space, inside the 3D generated shape of the breast [10], [11]. Therefore, a light benchmarks raster is implemented. 3D reconstruction might be further done [22] ÷ [25], but this is increasing too much the computing costs for this early detection of a high, ab-normal activity area.
It is possible to use a rectangular shape projected or a circular one, in order to generate the radiometric display.
The designed protocol, necessary to compare the body normal and abnormal microwave radiations for breast cancer diagnosis flow is:

- physician preliminary examination
- patient positioning for repeatable, systematic results;
- multidirectional thermography detection and capture in order to have a 3D initial non-invasive thermographic reference, to compare with and to reinforce the finally detected microwave map;
- light-spots projection, epipolar data acquisition with calibrated video-cameras, for an accurate 3D breast shape reconstruction;
- microwave emission detection, captured by the help of a special microwave radiometer, in a totally shielded microwave environmental protection room; systematic scanning of a symmetric selected area from different spatial directions; symmetric and correspondingly disposed microwave data aquisition;
- registration of the spectral energetic density in each point of the designed microwave emission map.
- microwave emission spatial map reconstruction;
- comparison of the microwave body emission areas to the previously detected thermography map.

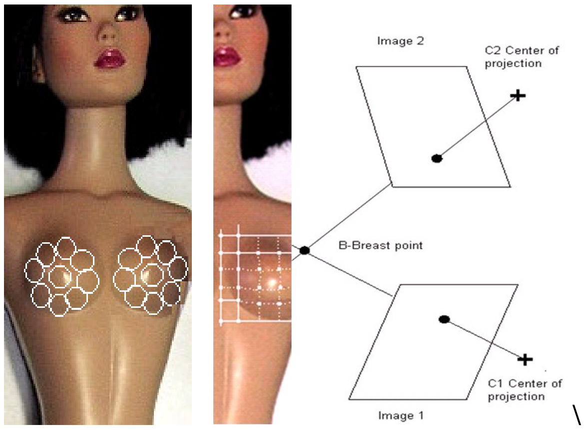


Fig. 6. Breast benchmarks:
two methods for systematic measurements.

Body positioning is priory executed by a spatially localization of the human body in the special designed microwave-shielded camera, on a special designed bed, in a reversed posture (preferably the patient is placed face down).
This way the coordinates are taken in a well established registering system.
Microwaves are displayed in spectrum just under the infrared and millimeter wave band.
To detect microwave radiation we may use the radiometer or we might also use two microwave receiver low-noise converter (LNC) in 3-4 GHz and 10-12 GHz band.
Obviously, the installation output contains both its own noise and the thermic-noise received by antenna.
Choosing of the operation frequencies depends on the intensity of electromagnetic radiation, (frequency augmentation attires intensity increase, according with Planck's radiation laws).

The radiometer values are to be registered by the help of a a dedicated software we designed.

Fig. 7. Installation containing the radiometer and the computer for microwave energy map registering

5 Preliminary Results Regarding Abnormal Area Detection

Preliminary results regarding abnormal area detection

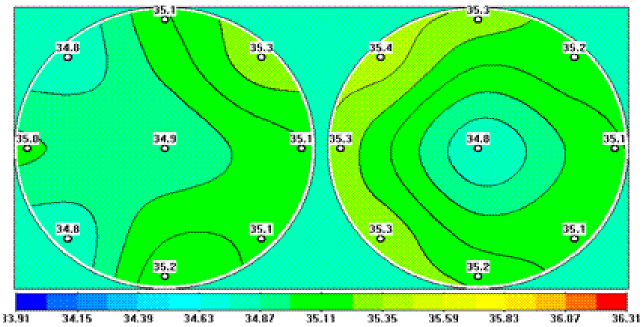


Fig. 8. Normal breast radiation detected (left and right sides)

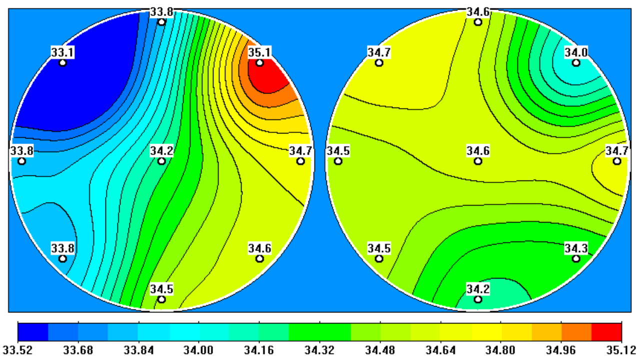


Fig. 9. Right breast cancer (TNM II stage)

Due to an increased activity of cell multiplication, certain areas are emitting more energy, that is easily detected in infrared domain and in the microwave range as well. In Fig. 8. a very slight difference between left side and right side is detected, therefore we have detected a normal person, normal case (values ranging from 34 to 36 Celsius degrees).

Not the same is the case of the following right breast cancer (TNM II stage). The tumour is in the upper inner quadrant of the right breast. By histology analysis, the diagnose is confirmed, cancer.

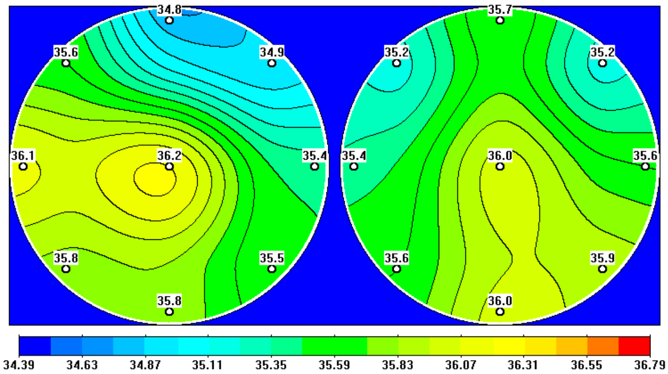


Fig. 10. Operated person (actual normal situation).

Another interesting case is on operated persons. Here the sequel are also able to induce false results. In infrared thermography they are giving very slightly different results.

Fig. 11. Infrared Image on an operated person

The image above is showing that almost imperceptible differences in temperature are perceived on scars.

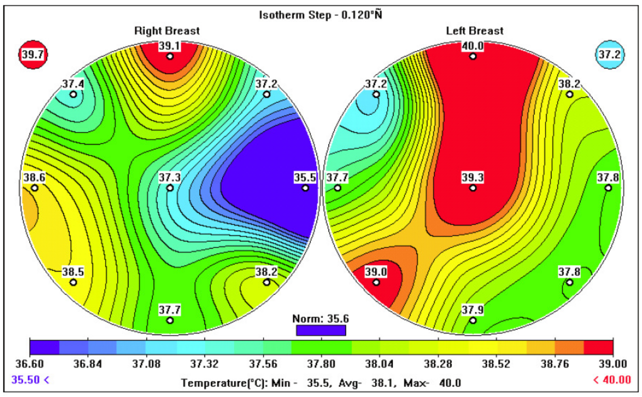


Fig. 12. Man, apparently pathologic breast radiation detected

The differences made between left and right sides indicated a symmetric display. Histology did not confirmed a cancer in such a case. Here, temperature differences were influenced by the heart muscle.

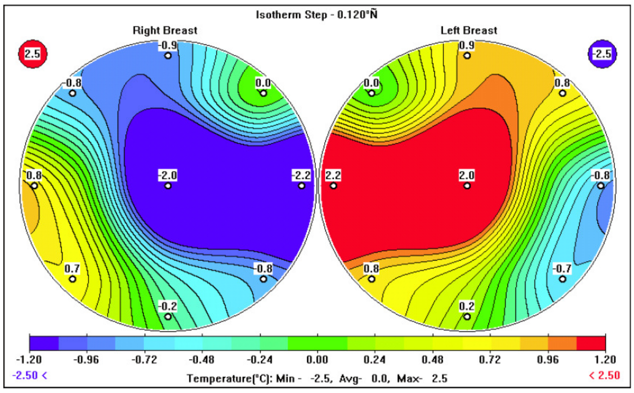


Fig. 13. Man, symmetric (normal) radiation: false thermo-effects detected, under heart activity influence

In the previous case, even if important differences between left and right images were remarked, the case is more complicated and needs further investigations.

6 Cancer Tumor Temperature.

It deserve to be mentioned here the study of Michel Gautherie in [22] when he published his data about tests made on cancer diagnosis. These data you can see in Fig.13. On the base of these data we have written a very simple equation of the tumour temperature.

$$T = k \cdot \frac{R^2}{D_T} \cdot B \qquad (1)$$

k – constant
R – tumour radius
DT – doubling time of the tumour
B - BIOT'S number.

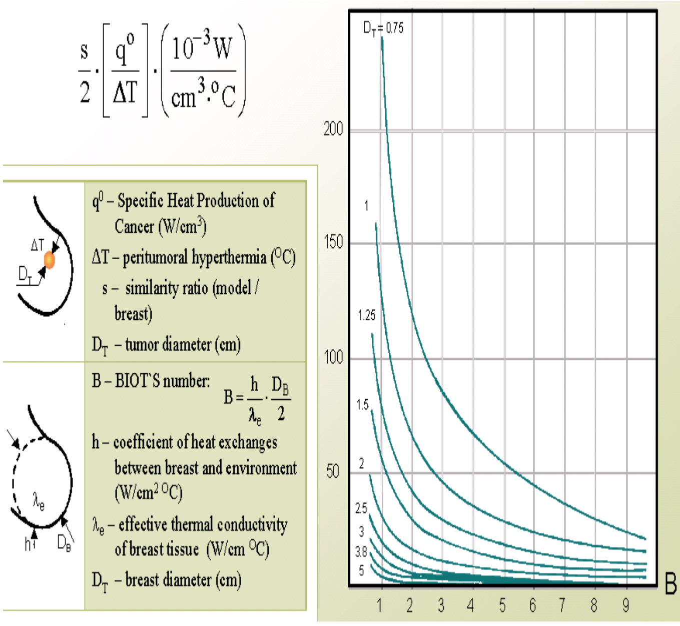
In the following image Fig, 14, (courtesy of Michel Gautherie [22]) we may see a rheo-electric simulation of heat transfer conditions in cancerous breasts:

This experimental chart is giving the specific heat production of cancer tissue (q^0) versus peritumoral hyperthermia (ΔT = temperature difference between the periphery of the tumor and the symmetrical area on the contralateral healthy breast), Biot's number (B), and tumor diameter (DT).

These curves, fitted by hand from the analog model of heat transfer, allow direct evaluation of q^0 from measurements of geometric parameters on mammography (s, DT, and DB), and thermal parameters (ΔT and Δe).

On account of the ranges of variations of Δe and DB, q^0 does not depend on tumor depth.

The coefficient *h* may be assumed to be constant and equal to 1 x 10-3 W/cm^2/ ^{o}C under controlled conditions (room temperature at 21 ± 1°C, no air draughts).



Fig, 14. Rheo-electric simulation of breast cancer heat transfer conditions (courtesy to Michel Gautherie)

Taking into account these data, "the false-friend" results and diagrams are able to be removed.

7 Conclusion

This research is an interdisciplinary attempt, in order to improve the cancer diagnosis efficiency. It is realized under the scientific management of Bioengineering Faculty, Medicine and Pharmacy University, "Gr. T. Popa", Iaşi, in an Excellence Research Contract, CANCERDET. The study has to be continued some years, with a survey of the patients in the Oncologic Clinique, in order to permit the formalization of the parameters and rule-base of a semi-supervised automatic decision system, helping both patients and physicians. Microwave medical imaging is a new technique and our full-equipped laboratory is a challenging attempt in order to develop it. Non-invasive methods in breast cancer diagnosis are presenting incontestable advantages (low costs, repeatability, non-harmful). To situate the microwave emissions of the malignant tissue, the body microwave signals are measured with a special radiometer, the patient being placed in a shielded room. The microwave range, raise some problems of real spatial malignant tissue positioning, limited by the real breast shape. The results obtained by this way are compared with the results given by another parallel non-invasive method (thermography or optic methods [26], [27]), the two methods reinforcing each other, and influencing the expert's opinion in order to take a decision [28]. The research is continuing due to the very complex aspects implied.

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