MICROWAVE IMAGING AT 3 GHz FOR THE EXPLORATION OF TUMORS OF THE BREAST

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ABSTRACT

We have used a microwave imaging system [7] worked out by the "Centre Hyperfréquences et Semi-conducteurs" of LILLE.

First, we have appraised the method by measurements of **53** large tumors to optimize it.

After, we essentially used this device for the determination of the benignity or the malignancy of small breast tumors :

- 9 non palpable tumors with a mammographic aberration
- 9 tumors of small volumes.

These tumors could not be punctured for a cytologic examination.

The microwave radiometry enabled us to determine definitely the malignancy or the benignity of these lesions, which was confirmed by a histologic examination, after surgery . These first results are promising.

INTRODUCTION

Microwave radiometry has shown to be well suited in order to carry ou thermological investigations as far as moderately deep seated tissues are concerned. A process of microwave imaging working at 3 GHz led to an informatic mapping of the radiometric intensities in terms of colored images.

At first, this system was studied by measurements made on large tumors.

After improvement of the technology and methodology, il is now principally used for the exploration of small tumors which cannot be punctured for a cytologic examination.

MATERIAL AND METHODS

Description of the imaging process

The image reconstructed from the radiometric intensities measured at an important number of points of an area defined on the body is a qualitative information about the temperature distribution which is present in the depth of the tissues accessible to the radiometric measurement (typically 3 or 4 cm) [1].

A multiprobe radiometric system includes a set of 6 probes sequentially connected to the receiver by a multiport switch [5].

The clinical evaluationsare based on the comparison of two radiometric images. One of them is obtained on diseased tissues. The other one concerns the symmetrical part of the body which provides a reference image. In such a process, all the radiometric temperatures measured after a calibration of the system in water at a known temperature, are within a temperature range which defines a scale of the colors on the screen of the system.

Methods of explorations and technical improvements

The exploration essentially leads to the characterization of the benignity or malignancy of a tumor in a breast area where the clinical examination or/and the mammographies predict for a tumor, even if the lesion is not palpable.

The patient lies down on a table. The "**tumoral region**" is marked after clinical examination and mammographic study. (Fig 1)

Then, a "**reference region**"is marked on the other breast ; it is the symmetrical region of the previous one about the median sagittal plane of the body. The acquisition of radiometric data is realized on a "**tumoral area**" of 7 cm X 7 cm, in front of the "**tumoral region**" or the "**reference region**".

Different modes of positionnings of the multiprobe have been defined, which led to the acquisition of radiometric data for an area of 7 cm X 7 cm.

In STAGE I, 39 large tumors have been explored in order to assess the feasibility of the system.

This one enabled us to acquire 72 radiometric data on the explored area.

We can interpret the data by the determination of two parameters (Fig 1) :

.Δ1 which is the difference of temperatures between the warmest point-image "t_T" of the **tumoral region** of the pathological breast and the temperature "t_R" of the symmetrical point-image of the reference breast.

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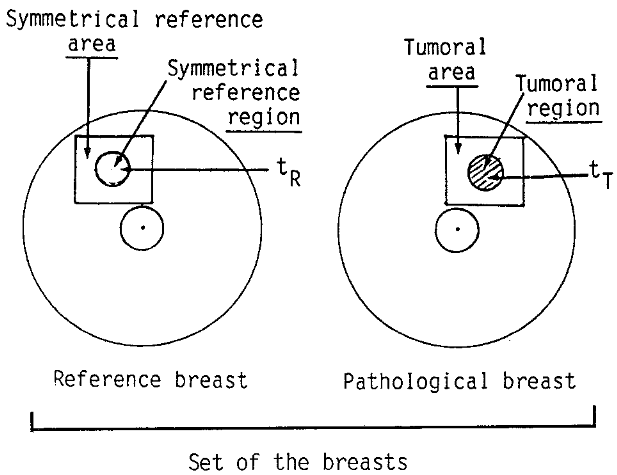
.$\Delta 2$ which is the difference of temperatures between the warmest point-image and the coldest one of the **set of the breasts.**

$\Delta 2$ is determined by the upper and lower limits of the scale of the temperatures.

FIGURE 1



In STAGE II we explored 14 tumors of smaller diameters. But we came across a problem of resolution of the image.

In STAGE III we have extended our process from the acquisition of 72 to 144 points/image. On the explored areas, we made radiometric measurements from 5 mm to 5 mm [7,8].

We explored 19 tumors of very small diameters or non palpable ones. In these cases, $\Delta 2$ was very small ; so we came across problems of inversion of images because the skin was getting colder during the measurements.

So, in STAGE IV we decided to place the patients in a room thermostated at 26°C during 15 minutes before the exploration. It was possible to obtain a thermic equilibrium between the temperatures of the breast and the room, which was checked before and after the exploration.

We explored 18 other tumors of very small diameters or non palpable lesions showed by a mammography. In these cases, these lesions could not be punctured to do a cytologic examination. So it was very difficult to prove the benignity or the malignancy of them before the surgical operation which was made after with percutaneous preoperative needle localization. [2,6,9]

RESULTS

Stages I and II

In these cases we used a 72 points/image system. These ones enabled us to test the feasibility of the system on 53 patients with big neoplasic lesions.

Our first conclusions are :
- good adjustment of the probe with the skin
- possibility to locate the lesion which is warmer than the normal tissues of the breast.

In these 53 cases, $\Delta 1$ and $\Delta 2$ are high, between 1.5° and 2°C.

Stage III

We used a 144 points/image system for the improvement of the resolution of the image for the exploration of smaller tumors.

In these 19 cases, $\Delta 2$ was smaller, between 1 and 1.5°C.

The results obtained in the stages I, II and III, proved that malignant tumors had rises of temperature compared with the healthy tissues more important than the benign ones, when they have no inflammatory reactions.

Stage IV

The results obtained after the three first stages led us to start the exploration of tumors of small volumes or unpalpable, in order to determine the benignity or the malignancy of them.

In that stage we improved the methodology of the exploration and we put the patients in a thermostated room.

The results are interesting as far as these 18 tumors are very small or **unpalpable.**

From the data, it was possible to predict the malignancy or the benignity of these lesions, which could not be punctered, before the surgical operation (Table 1), especially owing to the value of a **Radiometric ratio R** defined by the relation :

$$R = \frac{\Delta 1}{\Delta 2} \times 100$$

There is a good correlation between $\Delta 1$ and $\Delta 2$ data, the R data, the diagnosis of microwave imaging and the histology of the lesions.

If the lesion is a **malignant one**, the value of $\Delta 1$ is generally high, over 0.8°C. In the case n° 13, the $\Delta 1$ value is 0.79, but the value of the ratio R is high : 81. So the data are in favour of the malignancy.

If the lesion is a **benign one**, the value $\Delta 1$ is generally low, under 0.8°C. In the case n° 10, $\Delta 1$ value is 1.2°C, but the value of the ratio R is low : 57. So the data are in favour of the benignity.

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TABLE 1

Patient number	Clinical classi- fication before treatment*	Δ1	Δ2	Radiometric ratio : $R = \frac{\Delta 1}{\Delta 2} \times 100$	Diagnosis of microwave imaging	Diagnogis after surgery
1	T0	0.1	0.5	20	B	B
2	T0	0.4	0.8	50	B	B
3	T1	0.8	1.45	55	B	B
4	T0	0.5	0.9	55	B	B
5	T0	0.6	1.15	52	B	B
6	T1	1.06	1.06	100	M	M
7	T1	1.06	1.06	100	M	M
8	T1	0.6	0.84	71	B	B
9	T0	0.4	0.83	48	B	B
10	T1	1.2	2.09	57	B	B
11	T0	0.85	1.69	50	B	B
12	T1	0.1	0.5	20	B	B
13	T1	0.79	0.97	81	M	M
14	T1	0.53	1.06	50	B	B
15	T1	0.1	0.5	20	B	B
16	T0	1	1.07	93	M	M
17	T1	2	2.24	89	M	M
18	T1	0.7	1.25	56	B	B

B : benignity M : malignancy

* T0 : unpalpable lesion

T1 : tumor with a mean diameter below 2 cm.

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Indeed :

- if the lesion is a malignant one, the upper limit of the temperatures is determined by the rise of temperature in the **tumoral region** which gets a relatively high $\Delta 1$; so $\Delta 2$ is high and $\Delta 1$ and $\Delta 2$ are closed to each others, then the value of R is over 80

- if the lesion is a **benign one**, it is the other way round :
  .the **tumoral region** does not present an important rise of temperature, and so $\Delta 1$ is relatively low
  .the physiological differences of temperatures in the explored areas, which give the value of $\Delta 2$, are important compared with the value of $\Delta 1$; so $\Delta 1$ is lower than $\Delta 2$, then the value of R is under 75.

As a matter of fact,

- if the lesion is a malignant one, **the radiometric ratio R**

$$R = \frac{\Delta 1}{\Delta 2} \times 100$$

  of $\Delta 1$ in relation to $\Delta 2$ is high, over 80

- if the lesion is a benign one, the radiometric ratio R is under 75.

CONCLUSION

The results that we have obtained by microwave imaging at 3 GHz, mainly for the very small and unpalpable tumors, seem to be better than those given by infrared thermography which, after having been widely used in senology, has almost been given up for the exploration of these tumors.

The results of other authors indicate that microwave radiometry may have useful applications in the detection of breast cancers [3,4,10].

The relatively small number of cases in our population of patients implies that our conclusions must be taken as tentative at the moment.

The first results are promising and we are intending to carry out our works about the exploration of the tumors of the breast.

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