2. INTRODUCTION TO CONTACT THERMOGRAPHY

Preliminaires on contact spectra-thermography

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Summary. A personal method of sequential analysis of Contact Thermographic (C. T.) pictures by means of a light source with a suitable line spectrum is described. The contact spectro-thermography (C.S.T.) allows the quantification of temperature values until thermic resolution of ± 0,l°C. The sequential isotherms give the best morphological and functional assessment of the vascular network. The C.S.T. performs a real time thermal angiography with challenge test. The computerized storage of the doubtful C.S.T. patterns could be utilized as a quantified risk factor in healthy women.

Key words: breast cancer, sequential isotherms, spectra-thermography.

A) INTRODUCTION

The development and steady increase of popularity of Contact Thermography (C.T.) as a diagnostic method in breast pathology are mainly the result of the possibility of achieving the detailed morphology of the breast thermal picture with simple and relatively low-cost means." However, this technique is still faulty versus infra-red tele-thermography (I.T.) due to the missing quantification of the thermal image. It is known that the quantitative aspects of T. exhibit a considerable interest for the objective information it supplies on both the thermo-morphologic and biologic levels in the evolution of tumours.[5]

In the present paper a method is described, which makes the C.T. examination quantitative by determination of the distribution of isotherms and the relevant temperature values by spectroscopic techniques, hence the term Contact Spectrothermography (C.S.T.). Moreover, isotherms are dicussed, in order to understand their biologic meaning.

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1. Introduction to C.S.T. requires a brief hint as to the structures and properties of **liquid crystals**, substances which occur naturally in a state intermediate between solid and liquid. These liquid crystals form the base of C.T.[2] With respect to their structure, liquid crystals may be differentiated into nematics, smectics and cholesterics.

a) Nematic liquid crystals consist of elongated molecules oriented along a preferential direction (director). The order is only orientational, whereas the positional order is missing.

b) Smectic liquid crystals are characterized by orientational order and also by a partial positional order.

c) Cholesteric liquid crystals, in an idealized albeit not rigorously correct model consist of overlapping molecular layers. Each layer consists of long ((optically active)) molecules which are oriented along a preferential direction (director). The various layers are slightly twisted with respect to each other (Fig. 1) so as to give origin to a helicoidal structure.[3] The reason for this type of molecular arrangement must be sought in the chiral symmetry of each single molecule, which is induced in the whole system by inter-molecular interaction.[6,8] A mechanical model contributed to a better understanding of this type of structure (Fig. 2).

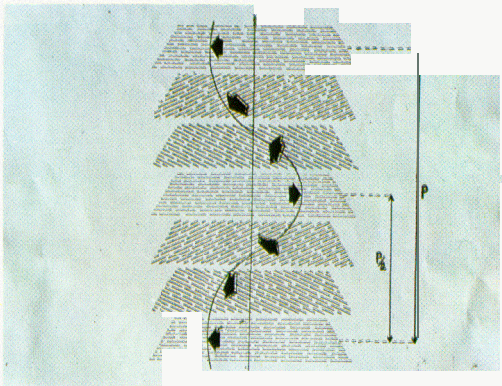


Fig. 1. Molecular arrangement in the cholesteric mesophase (idcalizad model).

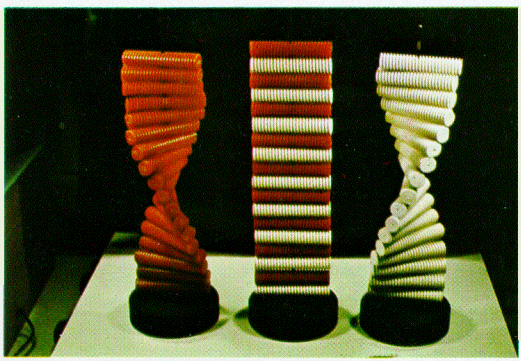


Fig. 2. Right and left-handed screws representing the minimum energy configuration in the colesteric mesophase (the 2 external piles represent enantiomeric structures, the central one a compensated structure).

The portions of endless screws represent the molecules with chiral symmetry. This is the symmetry, for example, of a dextrorotatory screw, which reflected mirror, gives the image of a screw tightening in opposite sense or vice-versa. A pile of these portions of screws affords a spiral-shaped structure by joint or by steric arrangement. Pooled quantimorphous structures may compensate partially or totally by varying the pith of helix to the infinite in the event of complete compensation, i.e. the middle pile, as in a real cholesteric mixture of compounds with a variable pitch.'

2. One of the most important properties of the helicoidal structure of cholesteric liquid crystals is the selective reflection of incident light.' This reflection follows the BRAGG's law[3] by which one may establish an univocal relationship between the wave-length of the maximum of selective reflection and the pitch P of the helix (knowing the incidence angle), which is in turn a one to one function temperature T.[7]

The analytical expression of this law for example for perpendicular incidence, is given by

$$\lambda_o = \bar{n}\, P\, (T) \qquad (1)$$

where «$\bar{n}$» is the average index of refraction of the liquid crystal. For simplicity, the selective reflection is seen by perpendicular incidence of the light on an isothermal surface covered with an appropriate cholesteric mixture. The bearn of white light (including all the radiations of the visible spectrum) scans from above the cholesteric structure (Fig 1). The light beam meets the first molecular layer and, through the effect of its amsotropy, undergoes a double linear polarization parallely and perpendicularly to the nematic director. The parallel component is reflected, whereas the perpendicular component is transmitted to the layer immediately below, which is slightly twirted.'

The light undergoes again a subdivision into a parallel riflected component and into a transmitted perpendicular component, and so on with the following layers, with the final result of having a circulary polarized light in one sense, which is reflected by the various layers, and a circularly polarized light in the opposite sense which is transmitted in the various layers.' Finally, the latter one is eliminated by absorption by covering in black the test surface. Therefore, the component of light reflected by the various layers is only persisting, which enhances its intensity at a certain wavelength being circularly polarized, only when it is reflected by layers of iso-oriented at half-pitch distance (BRAGG's condition). The macroscopic result is to have on the isothermal surface an even colour corresponding to the selectively reflected wavelength.

On the contrary, in the instance of a thermal gradient (Fig. 3), the helix pitch is variable and accordingly also the selectively reflected wavelength will be variable. Therefore, a range of reflected colours, which cover the whole visible spectrum will be possible. Since the colour

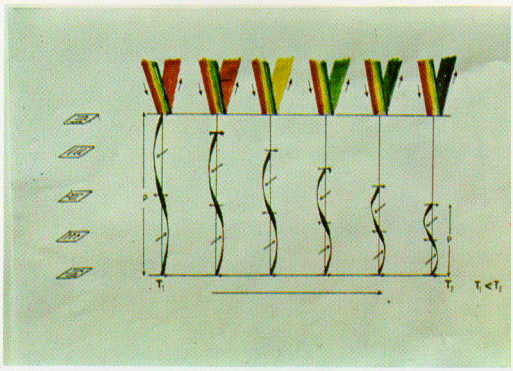


Fig. 3. Colours selectively reflected by a cholesteric structure having a definite pitch value (P) as a function of the thermic gradient.

affords only subjective **data** on temperature it is necessary to analyse spectroscopically the reflected light.

B) CONTACT SPECTROTHERMOGRAPHY

1. Spectrothermographic method

After having described the principles of liquid-crystal T, by stressing the quantitative reactions between selectively reflected wavelength and temperature, the methods to measure the distribution of temperature in a thermally uneven surface, such as the human skin, may be described.

A thermally inhomogeneous surface exhibits, however, isothermal areas which, covered with a liquid-crystal plate, show areas of the same colour (isocromatic areas).

The principle of C.S.T. is the determination of the wavelength selectively reflected by an isochromatic-isothermal area by spectral analysis and knowledge of the relationship between this wavelength and temperature. Therefore, it may be stated that C.T.S. is the method which enables to build up the image of an isothermal area as well as the corresponding value of its temperature by spectroscopic techniques. It is obvious that this applies to all the isotherms, i.e. **for** the whole chromatically uneven thermal image. These are the essential points of the method (Fig. 4):

a) the area of interest is covered by a *plate*[9,11] containing properly dosed micro-capsulated cholesteric mixtures and thus responding in a suitable thermal interval;

b) the plate is illuminated from a *line-spectrum source;* [9]

c) this image is photographed by placing in front of the lens of the camera some filters in sequence, which select the spectrum lines of the source, so that for each filter a photogram is achieved which evidences the relevant *isochromatic-isothermal area;*

d) finally, the *appropriate values* of *temperature* are assigned to the isotherms by reading the diagram wavelength- temperature.

2. Spectrothermography unit

This method has been operative by creating an equipment (Fig. 4), which enables one:

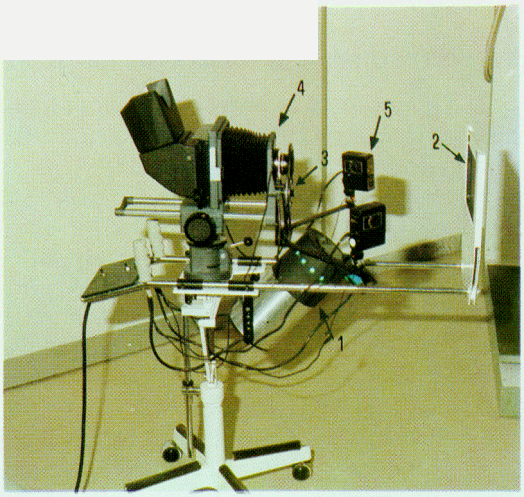


Fig. 4. Spectrographic unit(laboratory prototype). 1) alight source with discontinuous spectrum, i.e. a line-spectrum source; 2) a plate of liquid crystals with appropriate thermal resolution: 3) a monochromator consisting of a set or suitable filters; a) an instant camera; 5) a flash with continuous spectrum.

a) **to** *record photographically* the traditional multichrome thermograms;

b) to *separate various isothermal areas* in distinct photograms;

c) **to** *measure the temperatures* of these isothermal areas.

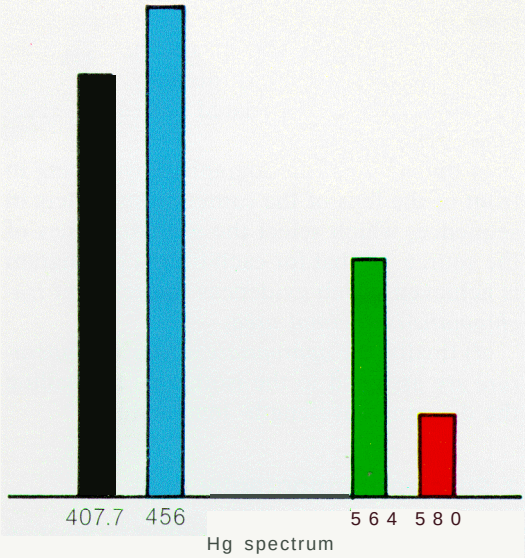


Fig. 5. Lines of the mercury emission spectrum in the visible region.

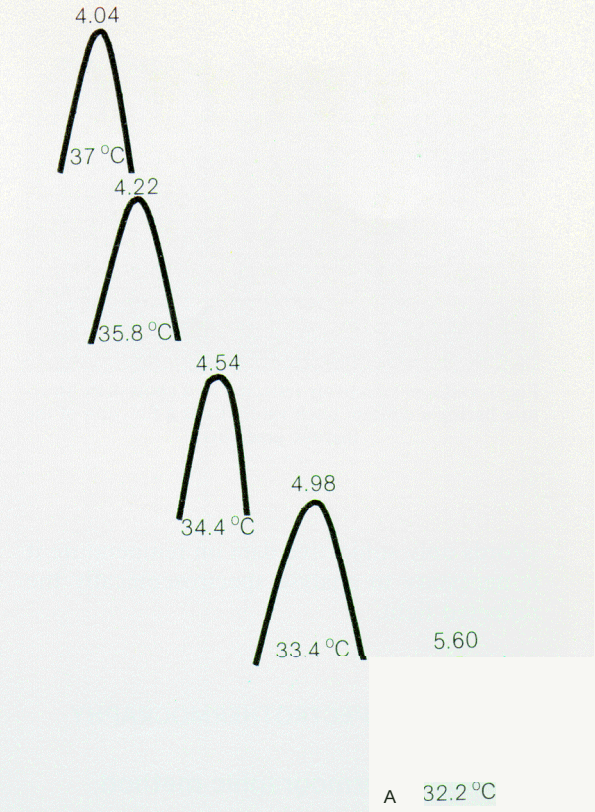


Fig. 6. Spectrum curves of circular dichroism at various temperatures, whose maxima are coincident[3] with the maxima of selective reflection for light perpendicularly incident on the plate.

3. Spectrothermographic procedure

a) Separation of isotherms: the discontinuous spectrum light cutting in the liquid-crystal plate is emitted by a mercury lamp.

The whole energy radiating in the visible of the lamp is virtually distributed into 4 lines (Fig. 5) which are very narrow, namely sufficiently monochromatic. These 4 wavelengths, before reaching the camera, are selectively reflected by the liquid crystal plate in correspondence with 4 different isochromatic-isotherma1 areas. Inserting now, between the camera and the plate, some filters in sequence, which serve as monochromator, the 4 isotherms are separated into 4 distinct photographs.

Since it is possible to build up some plates responding at different thermal intervals, the number of isotherms may be increased to comply with all the diagnostic requirements in breast C.T.

b) The *quardfication of isotherms* is obtained ascribing to the various isotherms a temperature value, according to a diagram which shows the wavelength (A,) of the maximum of selective reflection as a function of temperature (Fig. 6).

The shift of these maxima at the change of temperature is plotted (Fig. 7) and is an example of calibration curves of liquid crystal plates. The values read in correspondence with the lines of the spectrum lamp (404.7 nm, 456

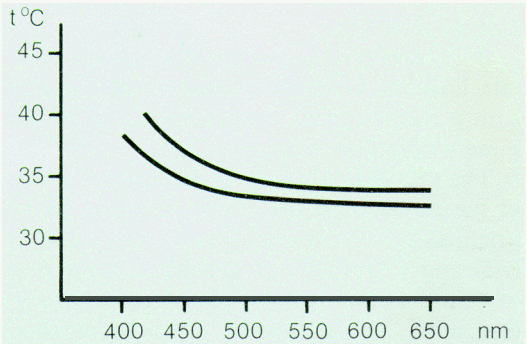


Fig. 7. Relationship between Circular Dichroism max and temperature. Typical example of microincapsulated cholesteric mixtures usually employed in C.T.

nm, 564 nm, 580 nm) are the required temperature values.

The hyperbolic trend of calibration curves makes the measurements of temperature (t) more sensitive at the longest wavelengths, where error $\frac{\Delta t}{\lambda_1}$ is very small. Therefore it is preferable to read the t-values only in correspondence with the lines 580 nm, 564 nm and 456 nm, omitting the lowest at 404.7 nm.

c) Spectrothermographic breast pictures.

The C.S.T. examination refers to both mammae, starting with a single plate. Whenever intermediate temperature values are required, other plates with different thermal intervals are to be used. Fig. 8 demonstrates the high selective power in the thermal picture of the breast, as well as the exact quantification of the temperature value.

C) DISCUSSION

1. AdVantagea of contact spectrothermography

At this point, in view of the possibilities of the method, the advantages and the interesting aspects in comparison with the other T. techniques at present in use in diagnostic of breast pathology are listed.

a) very *low costs.* The C.S.T. method is comparable to I.T. and sometimes more reliable as far as contrast, thermal resolution, etc. are involved.

b) Opposite to panchromatic conventional C.T. examination, the C.S.T. method allows a *better comparison* between the 2 breasts.

c) Concerning the diagnostic clinical value, C.S.T. through the quantitation of the T. image, contributes to its *objectivation,* which is presently missing in usual C.T. (Fig. 9). In particular, the vascular network is well defined both from the morphological point of view, and from the thermal one. The close correlation between the tumoural growth rate and its thermogenesis justifies the interest of these remarks. A hyperbolic pattern between the doubling time of tumour volume and the amount of heat of metabolic source produced for time and volume unit was described in the thermographic Literature.' This heat transmitted by convection from the venous blood flows is correlated with the temperature of the vessel itself. Concerning isotherms having intermediate temperatures or low temperatures, they are usually depending on the mode of transmission of heat by conduction to the skin, proportionally to bioconducibility of tissue itself.

d) The seriated isotherms at increasing temperatures allow a *real time thermal angiography* and consequently make several dynamic tests easier.

e) Moreover, this method enables to study the chronologic evolution of the *thermal behaviour* by quantitative criteria.

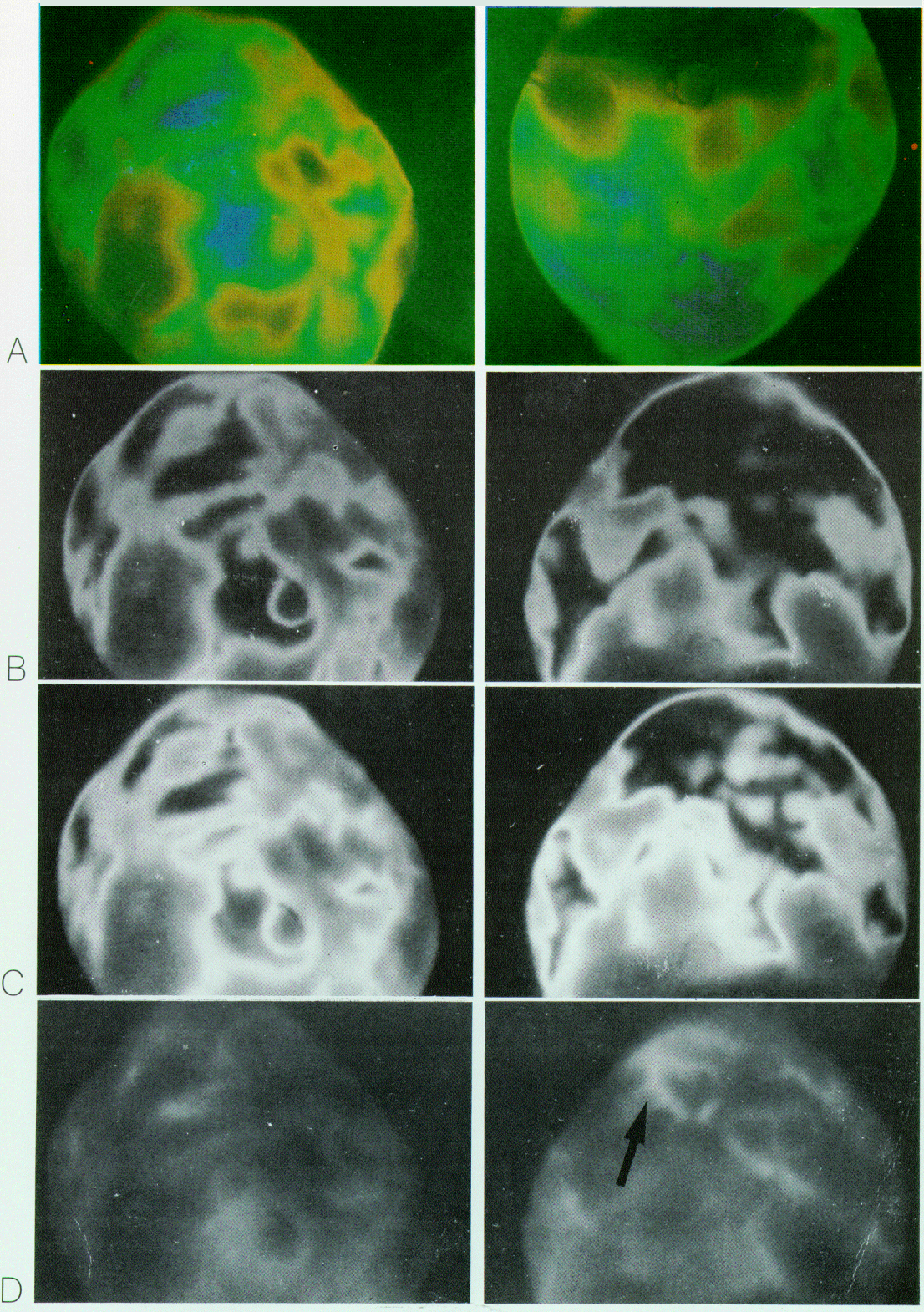
2. Future Of Contact spectrothermography

There are many possibilities in the use of C.S.T.:

a) The *quantitation of a large number of isotherms* and consequently the computerized analysis makes the calculation of average temperature easy; indeed, they are given by the summation of the products of isothermal areas by the relevant temperatures divided by the sum of the areas themselves ($\bar{t} = \frac{\Sigma A_i t_i}{\Sigma A_i}$).

b) The objectified *evolution in time* of a significant isothermal profile (e.g., hyperthermal vascularization) and the established average temperature for a large number of cases could be utilised to statistical codings of suspect patterns.

These findings could be considered as a preclinical sign of hidden breast disease or as a risk factor in healthy women.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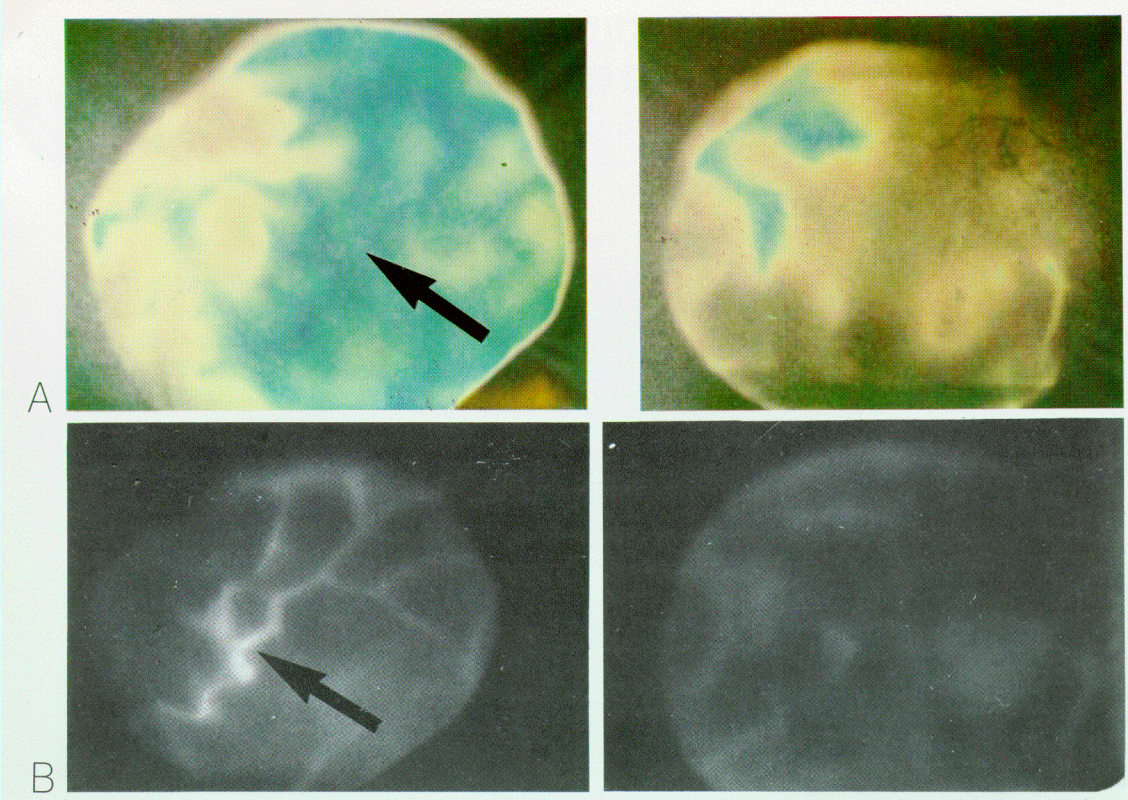

Fig. 9 A-B. C.S.T. of both breast. A) Conventional C.T.: the arrow shows a large hyperthermic area with an ill-defined vascular network in the right breast. B) C.S.T. at 35.6 "C: there are no isotherms on the left breast; in the right breast the vascular- hyperthermic network is well evident (arrow).

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Fig. 8 A-D. C.S.T. of both breasts. In the left column the right breast is represented, in the right column the left breast A) Conventional C.T.: polichromatic pattern of the 2 breasts. Hyperthermic area in the upper part of the left breast without a well defined vascular tree. B-D) C.S.T. pictures selected on different isotherms of increasing temperature value. The selected isotherms are clear while the dark areas are of different temperature. B) C.S.T. at 31.5 °C. The picture reveals the cooler isotherms in the 2 breasts. The right breast is therefore cooler in comparison with the controlateral one, especially in the upper part. C) C.S.T. at 32 °C. In the dark area of the upper part of the left breast same new isotherms become evident. This thermal selection corresponds to the middle temperature of the breast. D) C.S.T. at 35.6 °C There is no evidence of isotherms in both breast with the exception of the upper part of left breast where a vascular hyperthermic tract is well demonstrable (arrow).

Thermographic findings as related to the menstrual cycle

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Summary. The purpose of this research was to evaluate the changes in thermographic breast patterns during the various phases of the menstrual cycle (days 1-4-i O-l 4-21-28). The preliminary findings confirm already published data showing a period of decreased mammary vascularization around the 21st day of the menstrual cycle. We believe that this finding can be an useful factor in thermographic breast examination in women belonging to the age group we examinated in which we observed the greatest number of false positive thermograms.

Key words: breast thermography, risk factors, menstrual cycle, breast vascularisation.

A) INTRODUCTION

The diagnosis of breast pathology especially cancer, must be as early and accurate as possible in order to be able to perform a radical and successful therapy.[2, 3] For this purpose, a large screening program has been introduced.' Besides the physical examination (P.E.), other techniques such as Diaphanoscopy (D.), Thermography (T.), Mammography (M.) and Cytological examination (C.) have been utilized. ' For each method the financial charge on one side and the risk or the disturbance for the patient on the other side must be taken in account. Contact Thermography (C.T.), is the most recent available method in a mass screening program.[4] The C.T. pattern of the breast depends upon the metabolic activity either directly (thermal background) or indirectly (vascular tree) demonstrated. It is even not the same in all women depending on their age and hormone levels (menstrual cycle, oral contraceptives, pregnancy, nursing, etc.). The C.T. examination provides vascular or metabolic characteristics that can be classified in function of the intensity, extension and vascular morphology. There is no fixed standard thermic topography; thermogenesis is dependent on the age and endocrine profile (menstrual cycle, presence of oral contraceptives, pregnancy); in each woman, however, the «thermal map» remains unchanged, within certain limits.'. [6]

'Aim of this study is to evaluate the modification of C.T. patterns during the menstrual cycle in order to identify the most favourable time for C.T. examination of the breast. This way, it is possible to decrease the influence of the physiological variability and to render the interpretation of C.T. findings most reliable.

B) MATERIAL AND METHODS

Fifteen volunteer asymptomatic low-risk women were studied. Women undergoing estroprogestinic treatment and those with irregular menstrual cycles were excluded from the study group. Ages ranged from 25 to 38 yrs. C.T. examination was repeated for 3 consecutive menstrual cycles, on the 1st, 4th, 10th, 14th, 21st and 28th day. Exams were performed keeping the air temperature ,time of exposure, posture of the subject and cooling time constant. The P.E. and C.T. examinations were performed by 2 staff physicians of the I.S.T. The C.T. pictures were compared in a double blind system by the 2 staff physicians so that the thermographic evaluation would not be influenced by the P.E. examination. C.T. pictures have been classified in 4 classes increasing in vascularisation (l-2-3-4).

C) RESULTS

Modifications of CT. patterns .during the menstrual cycle were observed in all women. The average C.T. behaviour in the 4 vasculari-

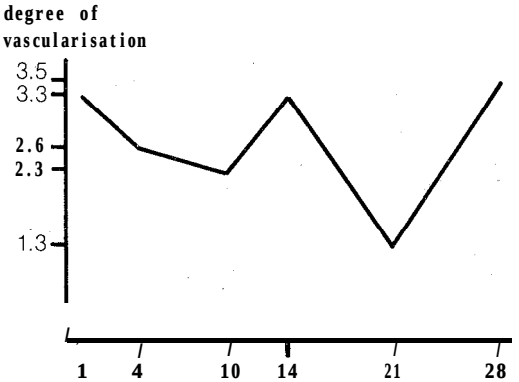

Fig. 1. Variation of vascularisation during the menstrual cycle: average values.

sation classes has to be distinguished from that observed in each of the 4 classes.

1. In the global series the following results were observed (Fig. 1):

a) Diffuse hyperthermia all over the breast (thermal background) was observed from the 1st to 4th day.

b) A *peak hyperthermic background and hyper-vascularisation* were noticed at the 14th day. Both the thermal background and the hyper-vascularisation were cancelled by the cooling dynamic test, persisting only in 3 women in the peri-areolar area.

c) A *peak of maximum vascularisation* was seen on the last day of the menstrual cycle.

d) The *lowest grade of vascularisation* was observed near the 21st day of the cycle.

No correlation between age of patient and amount of vascularisation was seen. In one woman persistent hyper-vascularisation was noted in the left upper quadrant, even on the 21st day. This woman was re-examined by the staff physician who found a slight glandular thickening at the site of the hyperthermia. The M. examination revealed a fibro-adenosis plaque. A biopsy confirmed the clinical and radiological results.

2. Taking in account each vascularisation class (Fig. 2), the thermal trend during the mestrual cycle has been differently influenced:

a) In the first *class* (very poor basal vascularisation) only a peak of hyper-vascularisation

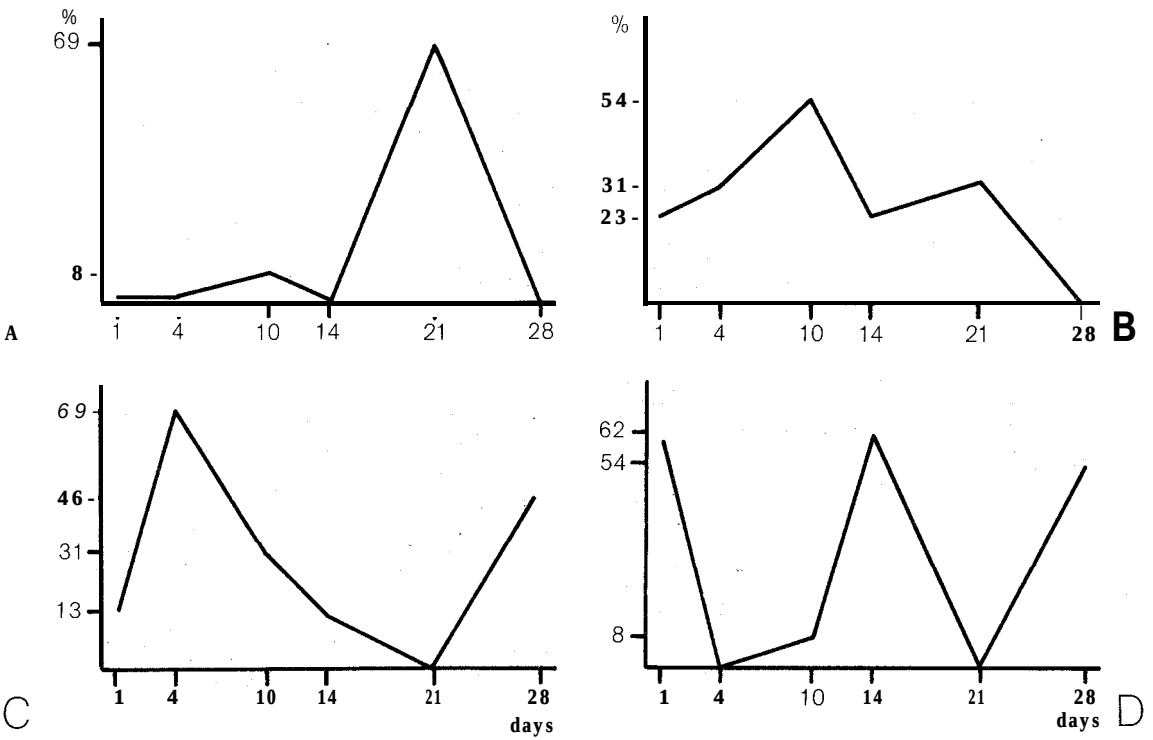

Fig. 2. Vascular distribution during the menstrual cycle. A: class I; B: class II; C: class III; D: class IV.

is identified at the 21st day. No other thermal modifications were observed during the other days of the cycle.

b) In the *second* class (poor basal vascularisation) there were 2 peaks of hyper-vascularisation, the highest one at the 10th and the lowest one at the 21st day.

c) In the *third* class (middle basal vascularisation) there were also 2 peaks, the highest at the 4th day and the lowest at the 28th day.

d) In *thefourth class* (rich basal vascularisation) there were 3 peaks of the same intensity, at the lst, 14th and 28th day of the menstrual cycle.

CI DISCUSSION

Before all, the variability of C.T. vascular modifications during the menstrual cycle in each vascularisation class must be emphasized. Nevertheless, referring to the average C.T. behaviour, it is possible to state that the collected information can be utilized in order to choose the optimal period for C.T. examination during the menstrual cycle. The high incidence of the C.T. false positivity in the range of age between 20 yrs-40 yrs, requires that the C.T. examination has to be performed in the period of minimal breast vascularisation. The personal results put this C.T.-time at the 21st day. This indication may be accepted whenever a mass screening has to be performed. On the contrary, when a C.T. examination has to be performed not as a screening but in a symptomatic woman, then the C.T.-time has to be chosen according to the information provided by the 4 class curves (Fig. 2).

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Biological bases in the thermographic study of breast cancer

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SummaryThe factors contributing to the thermographic picture in breast cancer are analyzed. In particular, the biological and functional features are taken in consideration, that is tumoural heat hyperproduction, hemodynamic abnormalities and transfer of hyperthermia to the skin. The technical features related to thermography are also shortly reminded.

Key words: breast cancer, heat hyperproduction, hemodynamic abnormalities, thermography.

A) INTRODUCTION

Since its early use in medicine, thermography (T.) yielded satisfactory results in oncology, in particular in breast cancer diagnosis. In fact, T. provides functional data, perfectly integrating the morphological data achivied by the other diagnostic methods.

At the present time both infra-red thermography (I.T.) and contact thermography (C.T.) are used without any difference; they have in

fact the same diagnostic accuracy,[1,5] although the thermic pictures they provide may be differently analysed. The C.T. pictures allow an ideal morphological analysis of the hyperthermic areas, whereas the I.T. picture allows to quantify more exactly the temperature differences (AT) among the various areas of the breast. Obviously, the T. map results from the superficial thermal distribution; the thermal changes induced by the abnormalities of the breast metabolism and vascularisation in the deeper layers are therefore only indirectly detectable by means of their heat transfer to the skin surface.

5) JUSTIFICATION TO THE THERMOGRAPHIC APPROACH TO BREAST CANCER

The justifications to the T. approach to breast cancer and to the T. pictures formation, are related to the following factors:

1. Factors related to the neoplasm and environment

They do explain the role of T. as a «functional» diagnostic technique; three are the fundamental factors.

a) Heat hyperproduction in the tumoural nodule: LAWSON[12] made the same remarks about the tumoural heat hyperproduction; this was confirmed[13] in 7 patients with breast cancer examined during surgery, with direct thermometry by means of thermocouples inserted in the tumoural mass and in the lateral toracic a. and v. The temperature of the arterial blood flowing to the tumour proved to be lower than that of the tumour itself; the venous blood temperature, although lower than that of the tumour, has always been superior than that of the arterial blood. The tumoural hyperthermia is therefore not dependent from the arterial blood inflow but only from the tumour itself. The tumour hyperthermia is due to a biochemical-metabolic abnormality of the neoplastic cell. Most affected is the glycolysis,[16] whereas the fat and protein breakdown cycles are substantially preserved:

a) the *glycolytic* breakdown presents a first step resulting in the breakdown of glucose into two molecules of pyruvic acid, with the production of four molecules of ATP; i) in the *normal cell* - aerobic conditions - the glucose breakdown is completed through the oxidative processes of the KREBS cycle up to the production of CO_2+H_2O, and of 16 ATP/molecule of pyruvic acid. On the whole, 36 molecules of ATP (4+16+16) with an energetic gain of 324 Kcal (9 Kcal/molecule of ATP) are produced. Being the potential energy of the glucose breakdown to CO_2+H_2O of 680 Kcal, 356 Kcal (52%) are obviously wasted;[16] ii) in the *tumoural tissue* - anaerobic conditions - the pyruvic acid produced by the glycolysis is not broken down via the KREBS cycle, being transformed into lactic acid: in this step, no ATP is produced whereas 2 molecules of it are even burned. In the anaerobic glycolysis 2 molecules of ATP are therefore formed, with an energetic gain of 18 Kcal. Being the potential energy of this system of 80 Kcal, there will be a waste of 62 Kcal (78%); I[6] iii) the *comparison between the 2 metabolic cycles* of the normal and tumoural cell, shows distinctly that one molecule of glucose has to be broken down, in order to produce 36 molecules of ATP in the normal cell in the KREBS cycle, whereas 18 molecules of glucose have to be broken down in the anaerobic cycle of the tumour cell in order to form the same amount of ATP. The global heat dispersion is therefore much greater in the tumoural cell (18 molecules of glucose x 62 Kcal = 1116 Kcal) vs. the normal cell (1 molecule of glucose x 356 Kcal).[16]

β) Recent studies on the huge energetic waste dependant from the biochemical abnormalities of the tumoural metabolism, better defined the tumoural thermogenesis and its strict relationship with the growth of the tumour itself. In particular,[5,6,7] the *specific metabolic thermogenesis* corresponding to the quantity of heat produced by the tumour/volume/time, shows the following relations: i) *typical pattern* for each kind of neoplasm;[5,7,19] ii) strict relationship with the *doubling time* of the neoplasm, being the heat production directly related to the tumour growth-rate;[3,5,6,16,19] iii) *highest values* in most cases in which a lymphatic spread of the neoplasm is present (carcinomatous lymphangitis, lymph-node metastases).[5,6]

γ) The *volume of the tumoural nodule* clearly

influences the heat production. In fact, although the neoplastic cellular growth rate gradually diminuishes along with the tumour volume increase - with proportional decrease of thermogenic activity -, the quantity of heat produced by the neoplasm increases proportionally to the neoplastic mass.[22]

b) Tumour-dependant hemodynamic abnormalities: the increase of the energetic needs of the tumour, as well as the pharmacodynamic action induced by the various substances it frees, alter the zonal hemodynamic patterns;[6,16,22] the latter are characterized by:

a) increase of the vascular network to and from the neoplasm; this is the most evident proof of the arterial hyperafflux and of the increased venous outflow. Hemodynamically, the tumoural nodule acts as an artero-venous listula because of the loss of the capillary barreer in the intratumoural vascular network.[22] This is the cause of the vascular anarchy, typical of the angiographic pattern of malignancies, whatever the affected site. The markedly increased arterial blood flow to the tumoural nodule and the following venous outflow result in hectasia, even neoformation of vessels which in normal conditions would not be detectable either at angiography or at thermography.[4,14,19,20,22,24]

This mechanism acts on all vessels encircling the tumour, being responsible of the vascular «star» and «ring» formation,[10,11,17,18,22,24,25] both typical features of a neoplastic hyperafflux. These vascular abnormalities are always close to neoplasm. The importance of vascular neoformation and hectasia has also a prognostic value, being related to the tumoural growth speed;[18,19,22,24,25]

β) *abnormalities of vascular morphology;* the neoplasm may be responsible of abnormalities, certainly less dramatic than the diameter changes and the vascular anarchy: this is due to stretching of vessels by infiltrative lesions, to compression by non-infiltrating space-occupying lesions, as well as to amputation or hectasia of vascular branches.[11,17,18,22,24,25]

c) Skin transfer of tumour hyperthermia: along with the tumoural thermogenesis, the heat waste is the other fundamental step in the formation of the T. pattern in the neoplasm.

The heat produced at different layers - in the neoplasm - is transferred to the adjacent tissues, thus to the skin, too: this, according to the following ways of heat waste:

a) tissue conduction: the quantity of heat transfer from the tumoural focus to the skin is strictly dependant from the thermic conductivity of the various tissues;[5,8,16] therefore, the higher the thermic conductivity of a tissue, the more evident will be the tumoural heat transfer to the skin. Truly, the fat is an excellent isolator because of its low thermic conductivity, whereas the glandular tissue is an excellent conductor. In presence of a lesion, oedema increases the heat conductivity of a tissue, whereas the latter is reduced by skin thickening.

The heat wasted by conductivity is responsible of the «hot spot» appearing on the skin overlying the neoplasm to which it is thus topographically strictly related; obviously, the deeper the tumour, the wider will be the skin hyperthermia, but .the lesser will be its value;[5,8,16,19]

β) *vascular convection*: the hectasic and newly formed vessels do not only provide to the tumour vascularisation, but they do also act as refrigerators, removing the heat excess produced by the neoplasm;[2,5,8,22] this, in accordance with the experience of LAWSON and GASTON.[13] This is especially achivied by venous system, mainly by the large veins; the quantity of carried heat is in fact proportional to the blood flow.[5,8]

Whereas the neoplastic vascular anomalities dependant from the hyperafflux (hectasia, neoformation, anarchy) are usually topographycally strictly related to the tumour, and are normally more evident in the T. pictures of superficially located tumours, the large veins draining the heat from the neoplastic territory have not such a strict relation with the tumour: they are in fact detectable even at great distance from the former. Sometimes, the large veins may be the only sign of a deeply located neoplasm;[5,22]

γ) *galactophoric convection*: the galactophoric ducts are another means of heat waste. For this reason nipple hyperthermia plays an important role in breast cancer diagnosis. Because of the richness of the galactophoric network and of its spatial distribution, there is not always topographic relation between nipple

hyperthermia and tumoural focus; the latter might be even very distant and deep.[5,10,15,18,22,24,25]

d) According to the different ways of heat waste, it may be clearly understood that everyone is responsible of the skin transfer of heat hyperthermia, in a different degree: the «weight» of each above mentioned way of waste is especially related to the depth of the tumour:

a) tumours with supeficial location: tissue conduction is the preferred way of waste, followed by convection. The T. pattern usually corresponds topographically to the tumour site (hot spot);

β) *tumours with deep location*: the ideal way of **heat** transfer to the skin is vascular convection, followed by galactophoric convection. A «hot spot» is, on the contrary, quite seldom detected (tissue conduction). This means that in many cases the T. pathologic pattern does not coincide topographically with the tumour site.'

2. Factors related to the thermographic diagnostic technique

T. (both I.T. and C.T.) is widely accepted to be the most reliable technique in the thermic analysis of wide skin surfaces: other techniques (thermometers, thermocouples, etc.), although sensitive, provide signals which are spatially too scattered and are therefore not able to create a precise thermic map.[16]

The diagnostic use of T. is ensured by the fact that two parameters are kept, by the presently available apparatuses, within ideal limits, namely:

a) sensitivity: it is minimum value of thermic gradient (At) necessary for the distinction between two points of the skin surface; a) in *infra-red thermography* the sensitivity is stricly related to the main features of the infrared detector; it is 0,2 °C;[5,16] β) in *contact thermography* the sensitivity is defined as the thermic gradient (At) necessary for the display of several colours on the plate.[22] It is strictly related to the kind of mixing of the cholesteric liquid crystals used in the plate.[9,22,23] The problem is quite complicated, since the relation «temperature/colour» is not linear:[2,9,21,22] in fact, the sensitivity is higher in the long wavelength (λ) reflected light (red colour) ($\Delta t \cong 0.8$ °C), being lower in the shorter λ (blue colour) (At = 1,4 °C); 22

b) linear resolution: it is the minimum distance necessary for the identification of two separate thermic signals: *a)* in *infra-red thermography* the linear resolution depends from the sensitive surface of the infra-red detector, as well as from the features of the optic system. It usually ranges between 2 mm (observations at a distance of one meter) and 3 mm (observations at a distance of 3 meters from the object);[15,16] β) in *contact thermography* the linear resolution **is** stricly affected by the lateral thermic spread, characterized by the presence of a chromatic halo around the T. image of the thermic source.[22,23] The lateral thermic spread is also strictly related to the nature of the support and the global thickness of the plate.[5,9,22] In the case the support allows a sufficient shielding effect on the lateral spread of heat, the linear resolution will be of about 1 mm.[22]

CI CONCLUSION

The ways of heat production, of hemodynamic adaptation, of heat waste as well as the strictly technical factors regarding T., are basic factors in the evaluation of the tumour thermographic map. Theoretically, no breast cancer would be missed at diagnosis. Truly, it happens that:

1) although breast cancer always sends a *«thermic message»*, the importance of the latter is extremely variable, being from time to time marked (highly thermogenic tumours) or very weak. At the same time many ((alternative)) heat sources, do exist: they have nothing to share with tumours, being therefore responsible of T. false positive errors.

2) Although a *distal transmission* of heat is present, the latter may sometimes be unable to reach the skin in a quantity sufficient to modify the thermic map.

3) Although T. is able to record the *skin thermic variations,* some skin abnormalities are present, which make it useless.

4) The *non specificity* of the provided T. information (hot-cold, with intermediate values): this makes the T. technique unfit to be

used alone in the diagnosis of breast pathology. T. has therefore to be inserted in a screening program: physical examination and mammography have, however, always to be the first-hand techniques; this way, also T. will be able to provide satisfactory results.

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