Acta Thermographica Supplement

Contact Thermography in Breast Screening

I - Cholesteric liquid crystals

A) INTRODUCTION

1. Liquid crystals (L.C.) are particular organic substances that, when passing from the solid to the liquid phase assume an intermediate phase (mesomorphic state). In this phase they act mechanically as liquids, yet exhibiting some optical characteristics of crystals. [21] The molecules of L.C. are arranged according to three typical molecular patterns (smectic, nematic and cholesteric <<phases>>, Fig. 1) each with differing physical characteristics.[21] Only L.C. in the cholesteric phase are suitable for medical applications (Fig. 1C).[6, ‘, 15, 16, 37, 40, 77] They are named <<cholesteric>> (C) because this type ofL.C. (C.L.C.) contains mainly compounds of cholesterol.[21]

2. Because of their typical molecular arrangement the **C.L.C.** present many optical properties [5, 11, 14, 15 17] the most important in medical use’being that of circular dichroism. This phenomenon occurs when a beam of unpolarized white light encounters’s layer of C.L.C., and it is broken into two components: one is transmitted, and the other is reflected (Fig. 2). When the wave length (h) of the reflected beam is in the spectrum of visible light, the surface of the C.L.C. appears coloured. The essential characteristic for the use of C.L.C. in medicine is the influence that temperature (T) exerts on the λ of a reflected beam, and therefore, on its colour.[5, 1l, 14, 15, 30, 40] This occurs because of the action of T on the arrangement of layers of C.L.C. The layers of C.L.C. placed one upon the other trace out a helical path (Fig. 3), whose pitch(p) is influenced by fluctuations in T. As T increases, *p* decreases; that is to say that the molecular layers move closer together (Fig. 4) and vice-versa. Since the λ of the coloured light reflected by the C.L.C. is directly proportional to the value of *p* (Fig. 5), the fluctuations of T – influencing the pattern of p - indirectly determine the colour of reflected light. In general, the spectrum of λ for each value of *p* is very narrow, which means that a relatively small fluctuation of T (consequently ofp) is sufficient to modify the colour of reflected light. In fact, there is a progressive change in colour as the fluctuations of T modify the p of the layers of C.L.C., and with it the λ of the reflected component (Fig. 6).

At relatively low T (high values of p), chro-

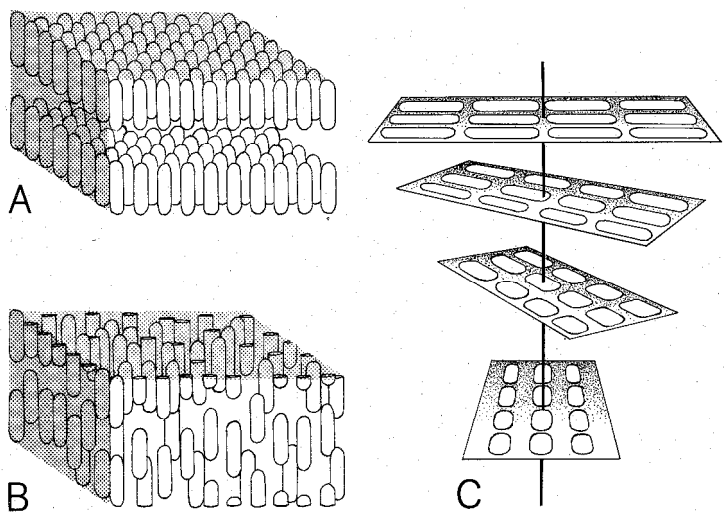


Fig. 1 A-B-C. *Scheme of the molecular arrangement in L.C.* A) *Smectic phase:* The superimposed layers are one molecule thick, with molecules arranged in parallel, and with the long axis perpendicular to the plane of the layer and, therefore, to the L.C. surface. B) *Nematicphase:* the molecules are parallel each other and the long axis is perpendicular to L.C. surface (as in the smectic phase); in this phase the molecules are not arranged in superimposed layers. *C) Cholesteric phase:* the superimposed layers are one molecule thick, with molecules parallel to each other, but with the long axis parallel to the plane of the layer, and notperpendicular, as in the smectic and nematic phases, In each layer the long axis is turned about 15’ as regards to the long axis of the contigous layers.

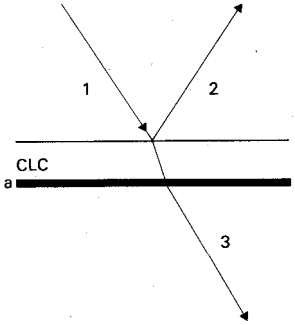


Fig. 2. *Circular dichroism.* The incident beam of white light (1) directed towards a cholesteric substance is split into two components (the one transmitted, the other reflected): the transmitted component (3) goes through the thickness of the C.L.C.: it should be eliminated in any thermographic application (by means of the absorbing layer a) in order to avoid the disturbing effect on the reflection by C.L.C.; the reflected component (2) present λ (and colours) depending on the molecular arrangement of C.L.C. (see text and Figs. 3, 4).

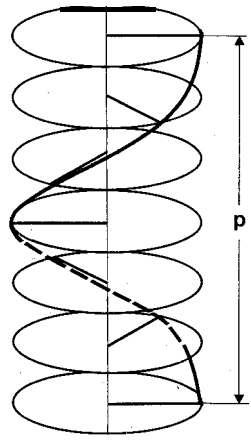


Fig. 3. *Helicalpath* of the one molecule thick layers in the C.L.C. In each layer the direction of the molecular long axis has a displacement of a given value (15') when compared to the molecular long axis of the above layer. The overall displacement traces a helical path. The helix is characterized by the pitch p (i.e. space required for a complete rotation of the layers).

matic tonalities corresponding to the longest h of the visible spectrum (red and its nuances) appear on the surface of C.L.C. (Fig. 7). Following chromatic variations they change to yellow, to green, up to blue-violet which is the shortest λ of the visible spectrum (low values of p). Within a determinate chemical composition of C.L.C. (cholesterol benzoate, nonanoate, chloride, etc.) the colour display is constant and repetitive.[15,30]

The C.L.C. are sensitive to a very wide range of T (from -20°C to +200°C).[15] By means of a special process of mixing, compositions are manufactured which respond to the thermal range to be studied (in the medical field the range is between +3O°C and +38ºC).[30,40]

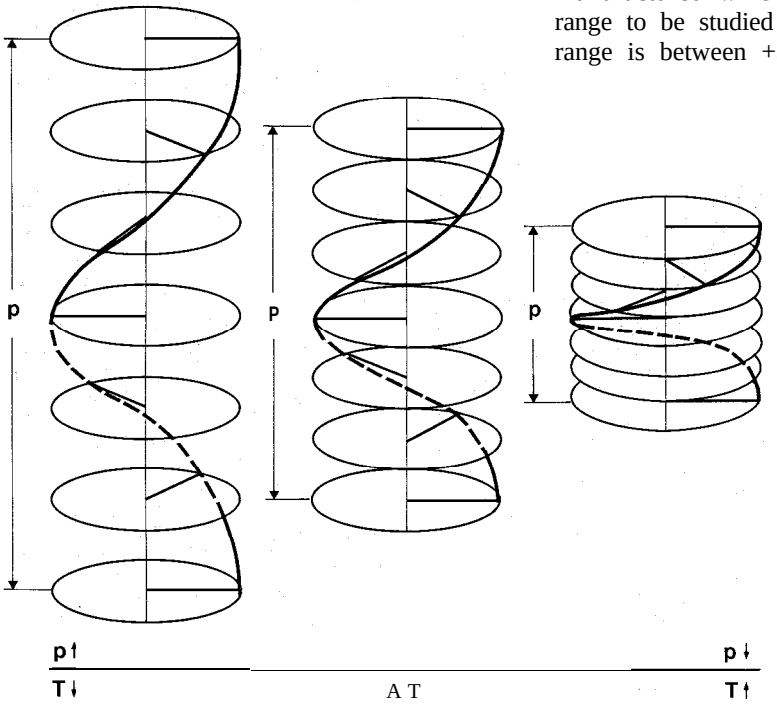


Fig. *4. Effect of T on p in the C.L.C.* The decreasing T causes the separation of the layers (increase ofp); but the increasing T causes the closing of the layers (reduction of *p).* The different colour displays of C.L.C. therefore depend on the *p* variations (see text and Figs. 5, 6).

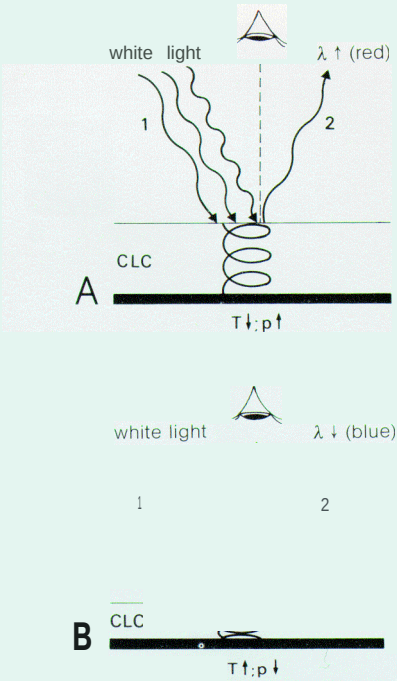


Fig. 5 A-B. *Application of the optical characteristics of C.L.C. in C.T.* The value of λ of the reflected beam (2) (i.e. the colour) is directly proportional to the value of *p*. Therefore T, influencing p, regulates the colour display of C.L.C. A) *At the minimum value* of T compatible with the emission of visible light from the C.L.C. (maximum value of *p*), the reflected beam is red coloured (longest λ). At lower T values, the λ of the reflected beam falls in the infra-red region and does not produce any visible light (C.L.C. ((blind area))). B) *At the maximum* value of T, compatible with the emission of visible light from the C.L.C. (minimal value of *p*), the reflected beam is blue coloured (shortest λ). At higher T values, the λ of the reflected beam is in the ultraviolet region, and is not therefore visible (C.L.C. <<blind area>>. The C.L.C. colour display and the visual detection from the observer are optimal when the incident white light beam and the observation axis are perpendicular to the plate plane.

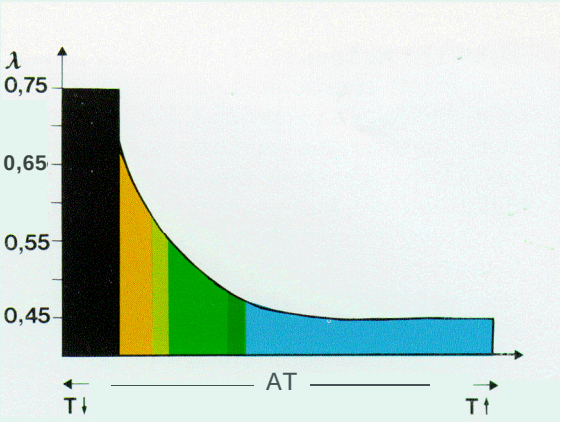


Fig 6. *Schematic representation of colour displays of a C.L.C plate with T change.* The visible spectrum reflected by *a* C L C. plate corresponds to a well determined T range (AT) and derives from Its <<bands of syntonization>>. The latter depends on the chemical composition of the C.L.C mixture. The lowest T values on which given plate is <<syntontzed» («lower thermal level») are shown by the red colour The highest T values («upper thermal level») are indicated by the blue colour. Intermediate colours (orange, yellow, yellow-green), demonstrate the colour display of the plate when T is fluctuating between the two levels of the «band of syntonization» (mod. from GAUTHERIE,[30])

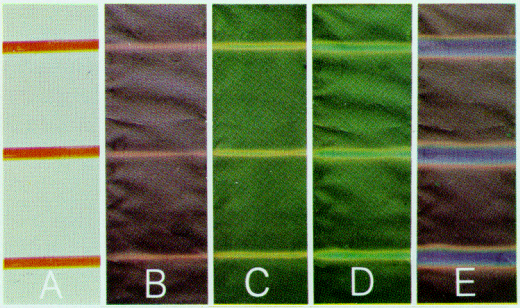


Fig. 7 A-B-C-D-E. *Representation of the colour display of a C.L.C. plate with «lower thermal level» at 33°C (ELC Thermo System Bayer, plate 33).* The plate is applied to a spiral shaped plastic straw placed in a grooved container made of thermal insulating material. The temperature of the liquid flowing through the straw progressively increases. A) *Straw in situ:* visualized by coloured liquid. B) <<*Lower thermal level*)); liquid flowing at 33°C. The straw image appears red coloured on the plate. *C),* D) *Sequence oftheplate chromatic variations with T fluctuations;* C) 34°C: green colour; D) 34.5°C; the green colour persists together with the appearance of small, orange coloured, chromatic halo (lateral thermal diffusion). E) <<*Upper thermal level*>>; liquid flowing at 35°C: blue colour. Slightly larger chromatic halo with additional colours (green and orange) caused by lateral thermal diffusion. It can be seen that progressive distortion of simple CT. image of the straw, has occured by a significant increase in diameter at the higher T values, due to lateral thermal diffusion.

B) MEDICAL APPLICATIONS OF C.L.C.

1. ivlethods of spreading C.L.C. on skin surface. The medical use of C.L.C. is based on the appearance and successive modifications of several chromatic displays, depending on variations in skin T, which appear on the surface of C.L.C. when it is applied to the skin over the area being examined. This is the difference between Contact Thermography (CT.) and Infrared Thermography, the latter being based on the remote detection of infra-red radiation emitted by the body surface.[22, 23, 32, 70] C.T. is performable only by direct contact of C.L.C. with the skin surface. It is obviously necessary to illuminate the C.L.C. by an external source of white light, be it natural, or preferably artifi-

cial.[30] The modalities for recording the surface T by C.L.C. consist of:

a) spreading or spraying C.L.C. in natural state on the skin surface to be examined.[6, 37, 40, 77] The many disadvantages include difficulties in spreading the C.L.C. layer, non-standardized chromatic display, excessive cost because the C.L.C. cannot be reused, and possible skin irritation. There are also contraindications of such procedures (skin abrasion or ulceration, psychological refusal to blackening of the skin on particular sites such as the breast) and these have led to general disuse;[12, 66, 82, 83, 86]

b) application of C.L.C. (incorporated within a light and flat support) defined as a <<plate>> [30, 83] with sufficient surface to cover the skin area under examination. C.T. is now carried out by the latter procedure.

C) THE THERMOGRAPHIC PLATE

The following report is based on the use of the Bayer E.L.C. Therm0 System equipment (Fig. 8).

1. Plate composition. The Thermographic Plate (Fig. 9) consists of three components, herewith described in the same order in which they are related to the skin surface:

a) thin, transparent, flexible, plastic base (Mylar), measuring 15 x21.5 cm, stretched on a rigid frame for insertion in the supporting structure of the equipment. The plate surface, to be applied on the skin, is sterilized by common disinfectants (alcohol, quaternary ammonium compounds, etc.). The plate cannot be sterilized using gas or boiling (which would irreparably damage the C.L.C.);" "

6) an intermediate black layer having optimal thermal conductivity, placed between the plastic base and the layer of C.L.C. This allows the absorption of the transmitted beam of light which, after passing through the layer of C.L.C. (Fig. 2) could be reflected through the plate by the skin.[30] Due to the protecting effect of the black layer, the observer sees only the beam of visible light, reflected by the C.L.C. of the plate, with λ (and therefore colour) dependant on skin T (Fig. 5);

c) the layer of C.L.C. has an average thickness of 100 μ; at the moment of manufacture the C.L.C. are enclosed in minute capsules (20 to 30 μ in diameter) with walls of a transparent polymer. The capsulation of C.L.C. has many advantages but also some disadvantages:[30, 74, 82]

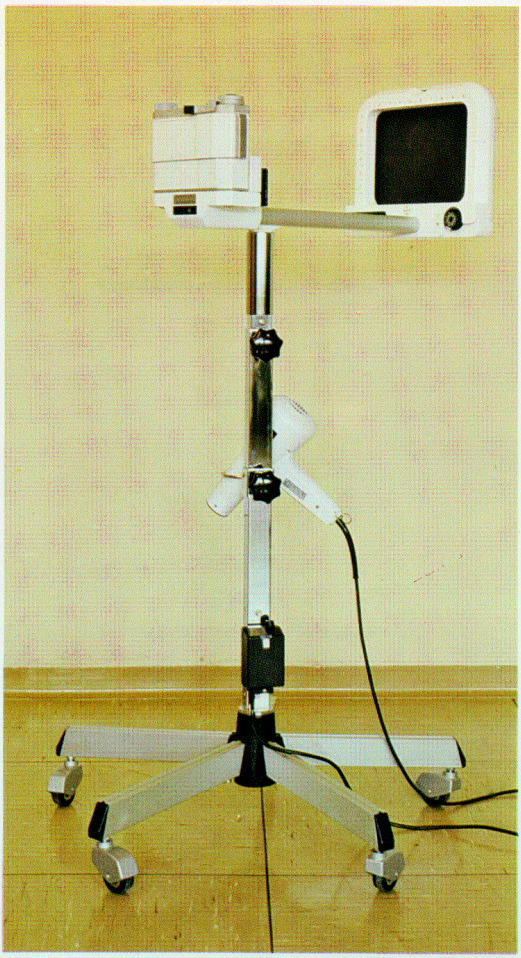


Fig. 8. *ELC Thermo System Bayer Equipment* for C.T. examination. The movable support carries the metallic frame. connecting together the sensitive component (plate) and the photographic recording system. The frame can be taken away from the support and manually used. The equipment is completed with the air cool fan. for the artificial cooling.

a) advantages: i) *protection* of *C.L.C.* from atmospheric impurities and from U.V. radiations (possible changes in the structural architecture of C.L.C. layer with consequent modification of their optical characteristics; ii) *unchangeable aggregation* of the compounds the C.L.C. mixture; iii) *prolonging of' the average* life of the plate;

β) *disadvantages*: i) *reduced definition of* λ for different values of T. This phenomenon

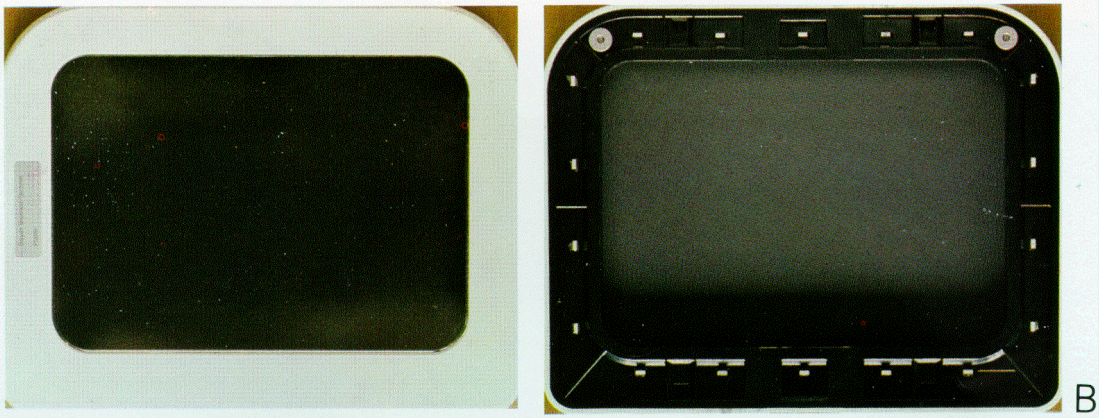


Fig. 9 A-B. *ELC Thermo System Bayer plate.* A rigid frame strains the plastic support with C.L.C. spraied on it (plate). The plate has two surfaces A) shiny surface: made by a plastic transparent base, to be applied on the skin, B) dull surface where C L C are spread, and C.T Image appears. Its handling should be avoided in order to prevent any damage to the C L.C arrangement and to their physical characteristics

greatly reduces the number of colour nuances; ii) *greater absorption of incident white light,* and therefore reduced intensity of the reflected rays (in practice, less brilliant colours).

2. Plates combinations. Due to the following considerations, C.T. examination usually cannot be carried out by using a single plate.

a) Depending on the particular mixture of C.L.C., each plate is sensitive only to a relatively restricted range of AT: band of thermal syntonization of the plate [30, 40, 74] (Figg. 6, 7). Thermal values not included in the «syntonization band» (both greater or lesser), fall in the «blind area» of the plate, and therefore do not result in a chromatic display. In fact, the C.L.C. reflected radiation does exist, but it falls either in the region of infra-red or ultra-violet rays, and therefore out of the visible spectrum (Fig. 5). Therefore, although the fluctuation range of skin T of medical interest is fairly moderate (30°C-38°C) [30, 34] a C.L.C. single plate is not sufficient to show such a temperature change. Consequently, it is necessary to use a set of plates, each one being characterized by progressive ((bands of thermal syntonization)).

b) Conventionally each plate is defined by the T corresponding to the lower thermal level of its own <<band of thermal syntonization)): for example, plate 31 means that the corresponding <<band of thermal syntonization)) is extended from 31°C to 34°C. The Bayer ELC Therm0 System provides 4 plates (31, 32, 33 and 34: Fig. 10). The colours which are displayed by each plate (in the range of its own <<band of thermal syntonization))) and during all progressive increases of T are obviously the same (Figs. 6,7). Because of technical difficulties in the mixing of C.L.C., the ((lower thermal level)) of each plate is approximately within ±0.25°C. The range of T displayed by the single plate («band of thermal syntonization») is variable: about 2°C for plate 31, about 3°C for the others. Taking into account that the lowest thermal level is placed at 31°C (plate 31), the total range of body T that can be explored using

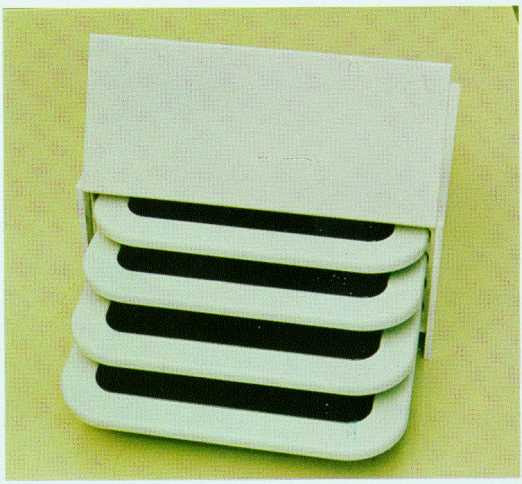


Fig. 10. *Set of thermographic plates (31-32-33-34) of the ELC Thermo System Bayer.* Description in the text.

the ELC Therm0 System Bayer, is therefore about 6°C (that is from 31°C to 37°C).

3. Plate efficacy. The criteria for evaluating the reliability of a single plate are as follows:

a) sensitivity: thermal gradient (AT) required for producing the sequence of colours on the plate. Plate sensitivity depends on the mixture of C.L.C. used in its preparation.[30, 83] In the ELC Therm0 System Bayer the AT is approximately 1.2°C±0.2°C. Nevertheless, it is necessary to point out that the relationship «temperature/colour» is not linear[16, 30, 74] (Fig. 6), because the plate sensitivity is higher at the longest λ (red: ΔT≅0.8°C) and lower at the shortest (blue: ΔT≅1.4°C). Each colour seen by the naked eye, therefore corresponds to a AT which progressively increases towards the shortest A;

b) spatial resolution: the minimum distance at which two adjacent points on the plate can be separately identified. The results are influenced by lateral thermal diffusion,[83] which (when the thermal source is considered as a point) forms a chromatic halo around the thermographic image of the thermal source (Fig. 11). This chromatic halo reduces the spatial resolution, as the C.T. images of the two sources tend to superimpose more readily. The halo becomes more marked as the T source is nearer to the plate's «upper thermal level».

In this situation, the plate is recording the peripheral thermal diffusion of the sources, producing the chromatic halo (Fig. 11B). The evaluation of spatial resolution is more precise if the source T is close to the «lower thermal level» of the plate's «band of thermal syntonization». In this case the peripheral thermal diffusion falls in the plate's «blind area», and therefore does not produce a chromatic halo (Fig. 11D). Under these conditions the plates of the ELC Thermo System Bayer have a spatial resolution corresponding to about 1 mm.

The plastic base of the plate slightly reduces its sensitivity, but increases the spatial resolution, due to its protecting effect on the lateral diffusion of heat;[30]

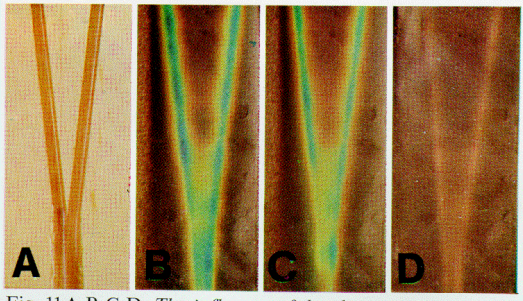


Fig. 11 A-B-C-D. *The influence of the chromatic halo on the plate's spatial resolution.* The experiment is the same as that illustrated on Fig. 7. The plate is applied to two straws converging like a V. A) *Straws in situ.* B) *Upper thermal level*: liquid flowing at 35°C. The straws images appear on the plate in blue, with a large chromatic halo caused by lateral thermal diffusion. Because of this diffusion, the C.T. images of the two straws overlap each other before the point of convergence, and are therefore not separately identifiable. C) The liquid contained in the straws has *T which corresponds to the appearance of the green colour*: 34°C. The chromatic halo still determines the fusion of the straws images before their real convergence. D) *Lower thermal level*: liquid flowing at 33°C. The straws images appearing on the plate are red coloured. There is no chromatic halo because the lateral thermal diffusion falls in the «blind area» of the plate (infra-red region). The C.T. images of the two straws are separately Identifiable to the point of convergence

c) thermal inertia: the time necessary to restore the primary helical arrangement of the C.L.C. layers, after modifications induced by T fluctuation. The thermal image only persists for a very short time (tenths of a second), after the plate is **taken** away from the skin surface. The plate's thermal inertia is directly proportional to the thickness of the plastic base.[30, 85] The rapid disappearance of the image from the plate is important from the operational point of view, because it reduces the time required for thermographic examination;

d) flexibility and endurance: plate flexibility permits the maximum adherence to the skin surface and the thinner the plastic base is the more effective it is.[83] The mechanical endurance (possibility of breakage) is in proportion to the thickness of the plastic base. It is therefore, impossible to have optimal conditions of flexibility and endurance in the sarne plate.

II - Contact thermography in senology

A) PRELIMINARIES TO THE C.T. BREAST EXAMINATION

1. Approach to the patient. As in any other instrumental investigation in medicine, C.T. breast examination needs a correct clinical overview of the patient. It is therefore necessary to perform a careful physical examination by means of inspection (lesions of the skin and nipple), and palpation (identification of masses and their careful evaluation: location, number, size, solidity, boundaries, mobility). When these procedures have been fulfilled C.T. can be proposed, correctly performed and successfully interpreted.

2. Optimization of C.T. examination. C.T. examination must be performed as accurately as possible and according to standardized rules. In order to obtain results comparable with future examination, the basic criteria to be followed are:

a) choice of the menstrual phase. The examination should be performed in pre-ovulatory phase - i.d. during the first 10 days after menstruation, when the breast is not congestive;[20, 23, 35, 41, 43, 44, 63, 65, 90]

b) psychological behaviour of the patient. Patient anxiety influences the C.T. pattern as it produces a diffuse vascular constriction. In such a situation the demonstration of vascular abnormalities can be missed. Therefore the examination should be repeated after tranquillizing treatment;[41, 85]

c) acclimatization of the patient to the room temperature. C.T. does not need an air conditioned room. Nevertheless it is necessary to keep the patient with uncovered breast and raised arms for about 5'.[68, 85] In some situations a ((preliminary cooling)) can be required, by the homogeneous diffusion of air over the two breasts by means of a fan (II, B, 1, e, a);

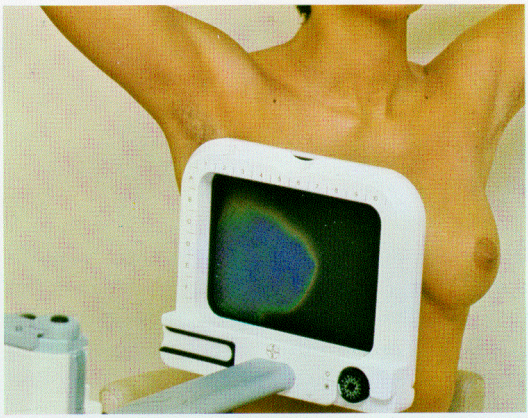
d) position of the patient. Except for particular situations the sitting position is preferred (Fig. 12 A-B). It permits the best approach to the upper quadrants. When the breast is particularly large, the lower quadrants can be better examined with patient in supine position (Fig. 12C). The arms must be kept constantly over the head in order to examine the axillar prolongations.[33, 34, 69, 85]

B) PHASES OF CT. BREAST EXAMINATION

The C.T. examination consists of two phases: the direct observation of the thermoscopic image, the observer looking its fast display on the plate after application to the breast surface (thermoscopy), and the successive recording of the thermoscopic pattern by photography of the more typical C.T. images, seen during the previous phase (*thermography*).[22, 40, 85]

1. Thermoscopic phase. This phase is the most difficult, because during it a series of optimal diagnostic images of each of the component the C.T. breast pattern has to be registered on the plate.

a) Breast vascularization. It is usually the most important component of the C.T. image (III, A). Optimal thermoscopic reproduction can be achieved when the vascular tree is perfectly recognizable everywhere, with the best possible resolution in relation to the breast background temperature. In other words, it is necessary that a very high thermal - i.d. chromatic - difference is present between vessels and background. Among the different colour displays of the plate, the green colour is the brightest and thus it is quickly visible by eye. For this reason the most important component of C.T. breast pattern (vascular tree) should be represented in green[66] (Fig. 13). This indicates the need for selecting a plate with a green band syntonized with the T value of the vascular tree. The choice of green means that the presence of some chromatic halo around the single thermoscopic image must be accepted in relation to the lateral thermal diffusion (I., C, 3, b) (Fig.



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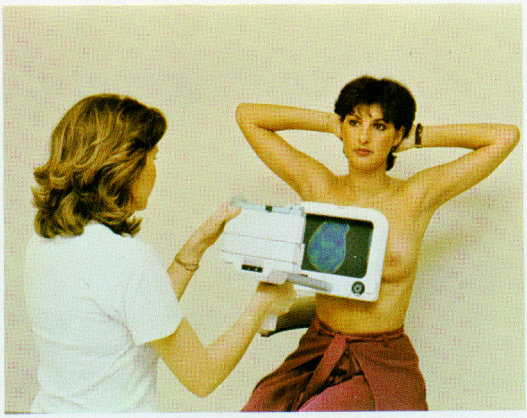

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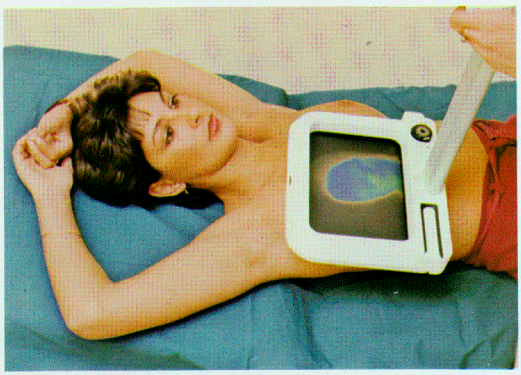


C

Fig. 12 A-B-C. *Positioning of the patient.* The C.T. examination is performed with the patient sitting (A and B): the lateral (A) and medial (Bj quadrants of the breast are examined in two successive times. In large breast, in order to provide a correct study of the lower quadrants. the supine position is recommended (C).

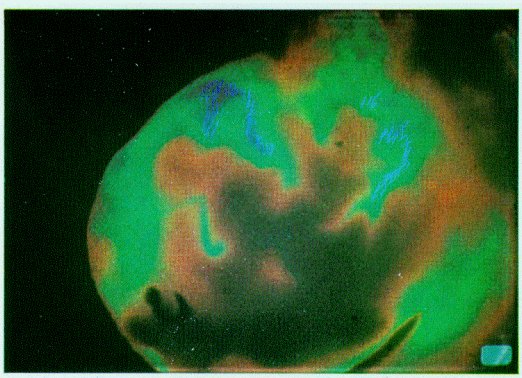


Fig. 13. *Chromatic pattern of the optimal C.T. image.* Left breast; lateral view; normal patient. The vessels are green – sea coloured – with a moderate chromatic halo – on the dark-red coloured background; the nipple dark-red coloured is surrounded by a black halo because of the insufficient adhesion of the plate to the areola.

11). In fact, the definition of the C.T. image could be even better if the chromatic halo is avoided. For these reasons it should be more advantageous to select a plate on which the vascular tree is represented by red (with T corresponding to the «lower thermal level»): in this condition the chromatic halo should fall in the «blind area» of the plate (infra-red region). However, the red colour of C.L.C. plates is less bright and consequently less visible by the naked eye. In practice, the chromatic halo extent can be reduced if the temperature difference between vessel and breast background is marked. The «preliminary cooling» is used for this purpose (II, B, 1, e, α).

b) Breast background. Its T is usually lower than the vascular tree temperature and should be at the same level as the ((lower thermal level)) of the plate ccsyntonization band)). The background should therefore appear red coloured red (Fig. 13).

c) Nipple. It usually presents the lowest temperature among other breast components (vessels and background). It is therefore coincident with the extreme values of the <<lower thermal level>> (red colour) or the plate's <<blind area>> (black: Fig. 13).

d) Serial use of plates. In clinical practice, taking into account the T values usually characterizing the vascular tree and other breast structures, the CT. examination should first be made with using the 33 plate. This produces a clearer colour display: green for vessels; red for background; black for the nipple.[34, 66, 85] However, when examining breasts containing a large amount of fat which are probably very hypo-

thermic (fat is a bad heat conductor),[13, 23, 41, 65] the examination first commences with lesser «lower thermal level» (32 or 31 plates).[66, 85] Similarly, when examining a probable hyperthermic breast (e.g. after a very prolonged oral contraception, during pregnancy or lactation) it is recommended that the first plate used should be the 34 plate.

It is unusual for a C.T. examination to be performed with a single plate. In fact, either the normal breast component or the possible abnormal component can present T values with a range larger than that of the <<syntonization band>> of the single plate (Fig. 14). Therefore, some of the components can be located in one of the-two <<blind areas)) of the plate. This makes the use of plates with different <<lower thermal level)) a necessity. As the malignant breast lesions are usually characterized by high T values, in practice it should be used a series of plates with <<lower thermal level)) progressively higher. When using higher plates, the breast components with T values located in the ((blind area>> of the plate, are canceled (Fig, 14). Therefore the serial use of the plates permits the insulation of the hyperthermic - normal or abnormal components - from those relatively hypothermic allowing in such a way their best morphological representation (Figs. *15, 52).*[34,66,69,85]

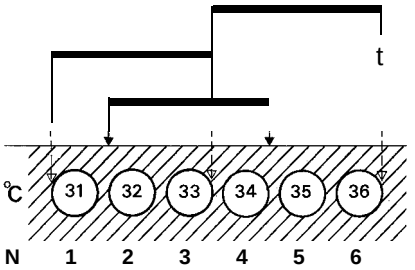


Fig. 14. *Scheme of the plates serial use.* Six breast components - normal or abnormal - each with increasing T values (from 31°C to 36°C), are considered. The plate A («lower thermal level» at 32°C) can identify only the components n. 2, 3, 4 because of the width of its «syntonization band». Therefore the components n. 1 («blind area»: infra-red) and n. 5, 6 («blind area»: ultra-violet) are excluded. The plate B («lower thermal level» at 31°C) permits to analyse the component n. 1, the n. 4, 5, 6, being excluded. The plate C («lower thermal level» at 34°C) analyses the components n. 4, 5, 6, the n. 1, 2, 3 being excluded.

e) Artificial cooling of the breast. It is obtained by a cool air beam homogeneously distributed by a fan (Fig. 16). The goals of the artificial cooling are two:

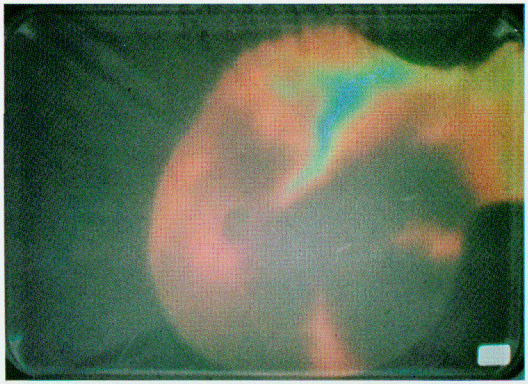
a) the *preliminary cooling* (l'-2') should notably decrease the breast background temperature that, when the climate conditions are unfavourable or when the blood supply is very rich, can mask the C.T. reproduction of the other mammary components, particularly of the vessels.[34, 47] The «preliminary cooling», therefore is useless in the fat and in the senile breast; i) the ((preliminary cooling)) should be considered *insufficient* when it does not produce the necessary temperature difference between breast background and vascular network. In this situation the cooling test should be repeated as long as good results are obtained; ii) the ((preliminary cooling)> has to be considered EX*cessive* when it causes the thermal levelling of the breast, avoiding the image reproduction on the plate. In this case it is necessary to wait for 2'-3' before repeating the thermoscopic observation;[62, 85]

β) *dynamic test:* the evaluation of the response to the cooling test of a C.T. abnormality (breast background, or nipple, or particularly, vascularization) can be worthwhile during the thermoscopic examination. The cooling causes a progressive decrease, quantitatively differentiated, of each single thermal breast image till its disappearance.

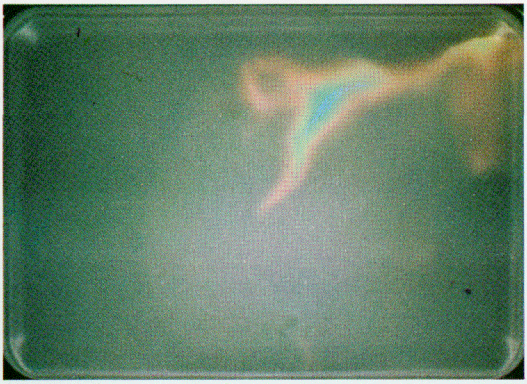
The time required for the <<cooling dynamic test>> cannot be standardized and it should be decided by the Senologist, according to patient C.T. pattern. The ((dynamic test>> is used when a diffuse hyperthermic area of mammary background should be minimized (in order to enhance the associated vascular abnormalities masked by the background temperature) or when the different response of inflammatory and neoplastic C.T. abnormalities has to be evaluated.[18, 52, 62, 66, 68, 85] In fact, the «dynamic test>> shows that the inflammatory lesions are reduced earlier and more extensively than the neoplastic ones.

f) Performance of the thermoscopic phase. It is handled as follows:

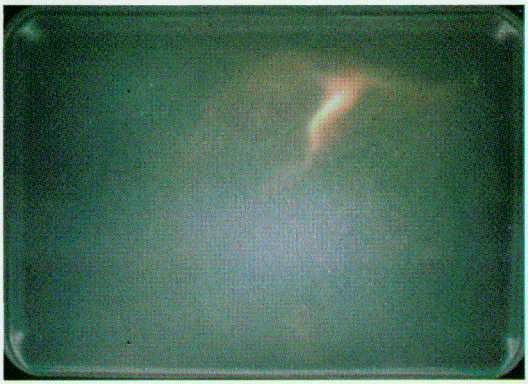
a) the plate, chosen on the basis of the preceding criteria, is carefully applied with increasing pressure, on the lateral quadrants of the breast. When the main vascular structures



A



B



C

Fig. 15 A-B-C. *Practical example of the serial use of plates.* Right breast; medial view: mastoses localized to the upper-medial quadrant. A) Plate 32 The medial peduncle and the corresponding main branch present a slightly Increased diameter with a loop-shaped course: marked chromatic perivascular halo. B) Plate 33. The breast background is canceled; the chromatic halo is reduced. C) Plate 34. The chromatic halo is cancelled; the morphology of the peduncle and of the main branch is perfectly visualized

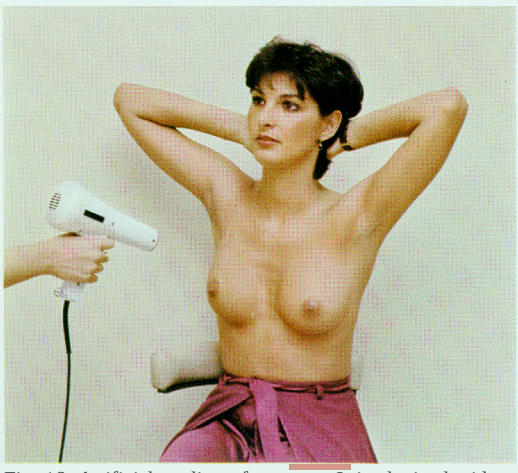


Fig. 16. Artificial cooling of *fhe breast.* It is obtained with a cool air flow. homogeneously distributed by a fan. The application time depends on the purposes of the cooling.

appear (lateral peduncle: III, A, 2, a, β) its course towards the areola can be followed by an ***alternate latero-medialplate movement*** (Fig. 17). The nipple usually hypothermic (III, B, 1) is the fundamental spatial landmark. If the use of further plates is not necessary, the thermoscopit pattern can be photographically recorded (II, B, 2);

β) the examination of the breast medial region can be performed with the same procedure except for an ***alternate medio-lateralplate movement*** in order to reach the black (cool) nipple landmark;

γ) the C.T. standard examination can be performed by these two views, obviously utilizing all plates necessary for the normal or pathological structures to be visualized. When the preliminary physical examination - inspection or palpation - demonstrates a breast mass existence, it is necessary to examine it by C.T. *special views,* in order to locate the suspected area by co-ordinates drawn on the skin. The reference points of the plate frame should correspond to these co-ordinates (Fig. 18); [85]

6) the C.T. examination differs from infrared thermography, because it shows only one breast at a time. This fact prevents the ***simultaneous comparison*** of the thermal pattern of both mammae. It is possible to partially overcome this disadvantage by approaching the two mammae so that the medial quadrants and the areolar regions can be analysed by a single plate (Fig. 19). Nevertheless the approach tes-

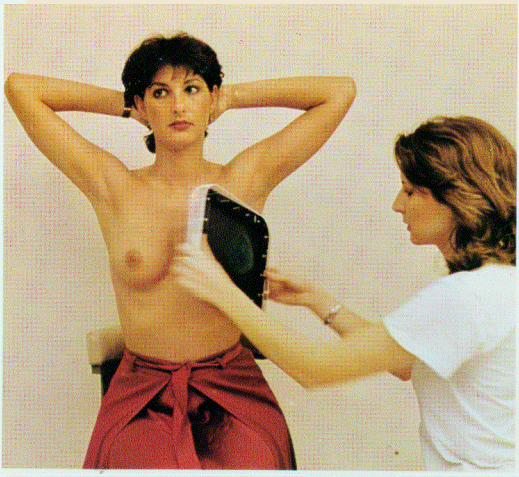


Fig. 17. *Alternate latero-medial movement.* The plate follows the course of the vessels, from the origin of the lateral peduncle to the areolar region. The vessels of the medial quadrants are analysed by a similar alternate medio-lateral movement.

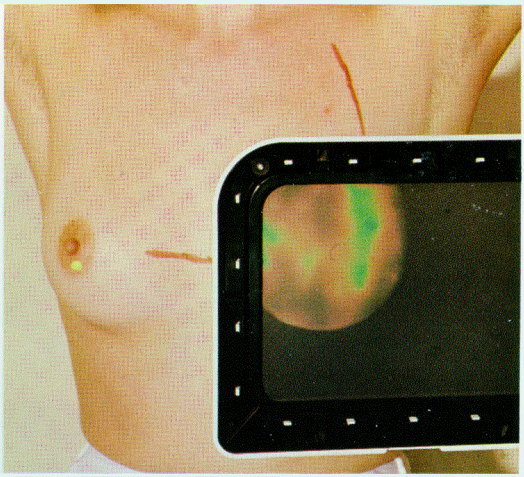


Fig. 18. *Analytical view.* In order to localize exactly on the C.T. image a breast lesion clinically palpable, two perpendicular lines are drawn by a dermographic pencil on the skin. In the same way, each C.T. image can be exactly localized on the breast surface, using the notches existing on the support frame (Fig 12)

ting both mammae modifies the normal course of the vascular peduncles and the peripheral blood distribution. This technical modality can be used only for identifying diffuse thermal differences which may exist between the two mammae (III, A, 2, g). On the other hand, there are some commercially available products allowing the simultaneous C.T. examination of both mammae (plates in the form of a bra: [38] these have the disadvantage of not fitting to different breast sizes; and plates modelling to the individual thoracic wall by means of a vacuum system).“” These methods have not been fully tested.

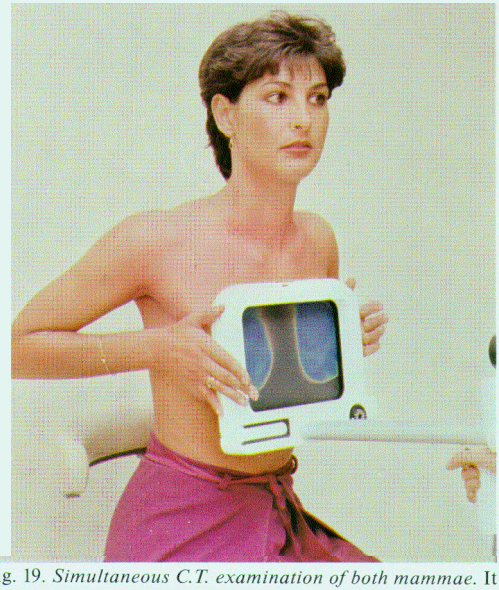
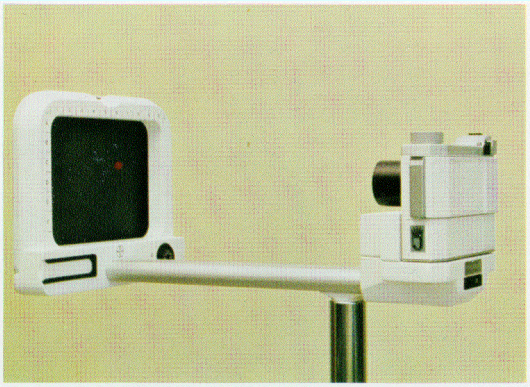


Fig. 19. *Simultaneous C.T. examination of both mammae.* It permits the direct comparison of the thermal level in the medial quadrants and in the areolar regions.

2. Thermographic phase. This is the recording of the thermoscopic pattern, which serves either to provide the Senologist with a more detailed breast analysis, or to permit an easier follow-up.

a) The C.T. system is equipped with a camera, located at a particular distance from the plate plane (Fig. 20). The camera may use an immediate (Polaroid film type SX 70 or the most recent combination of CU5 camera with Polaroid film type 668) or a delayed documentation film 24x36 for colour slides (50-64 ASA, day light, 5.500 k). Plate lighting is achieved by a cool flash light, incorporated in the C.T. equipment. The axes of the camera and of the artificial light source, should be perpendicular to the plate plane as the colour display of the plate and its visual appreciation are optimized when both lighting and vision are perpendicular to the surface (Fig. 5)[14 30]

b) The image numbering system for a com-



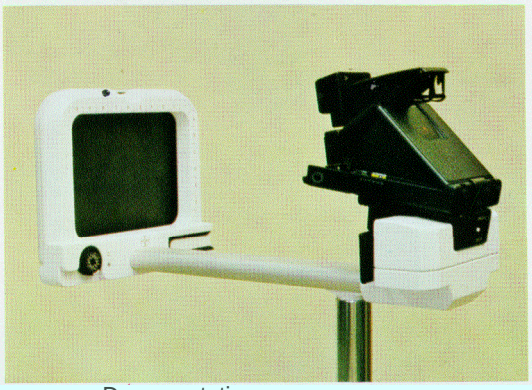


Fig. 20A-B Documentation of the C.T image. A) Photographic system on slides; B) Polaroid system. There is fixed distance between the recording system focus and the plate The light source for the documentation is obtamed by an incorporated flash

Fig. 21. *Viewer for C.T. images documented on slides.* Enlargement ×10.

plete documentation of a C.T. examination depends on the Department's requirements: i.e. the teaching Department may require more complete documentation. On average, each C.T. examination requires at least 5 images.

c) The choice of the recording material (Polaroid or slide film) depends on the type of patients who undergo the C.T. examination: the Polaroid documentation is advantageous for out-patient examination because of its immediate availability. Slide documentation is cheaper, and can be used for in-patients. Moreover, the Polaroid documentation does not require a further visual device, while the slide documentation necessitates of enlargement (Fig. 21).

III - Normal and pathological CT. signs of the female breast

The aim of this booklet is to define some guidelines for a more correct C.T. examination of the breast and for the identification of the breast pathological findings. The basic components of the breast, able to display C.T. images, are: vascularization, nipple, and background. Obviously, an isolated breast lesion can appear (it happens very often) either with multiple changes of the same component, or with involvement of more than one component (modification of the vascular tree associated with background and/or nipple changes). As it is not the aim of this booklet to describe all C.T. patterns in every breast disease, the Reader is asked to sintetize the abnormal C.T. patterns, herewith described, and to integrate them with the preliminary clinical approach.

A) VASCULARIZATION

1. Anatomy. The vascular tree represents the basic element of the breast C.T. pattern in women of fertile age, during the pre-ovulatory phase.

a) Breast vascularization: [7, 9, 48, 54, 55, 58, 72, 73] the following anatomical elements are considered:

α) *the arterial supply* (Fig. 22): mainly depends on subclavian and axiliary arteries: internal mammary artery (medial region); thorace-acromial artery (upper region); external mammary and infrascapular arteries (lateral region); intercostal arteries (posterior region). From these arterial peduncles originate the branches which form the peri-glandular tree, either on the anterior or on the posterior glandular aspect. The arterial pre-glandular tree is much more developed than the retro-glandular tree. For this reason, the gland is nearly entirely supplied by branches originating from the half-deep arterial tree (Fig. 23). From the peri-glandular arterial tree originate: i) superficial branches directed towards the slain, particularly in areolar and peri-areolar region (Figs. 22, 23); ii) half-deep branches directed to the *glandular parenchyma* (Fig. 23); iii) deep branches supplying the *retro-glandular structures* (Fig. 23);

β) *the venous drainage* utilizes the following routes: i) the *half-deep route* according to a

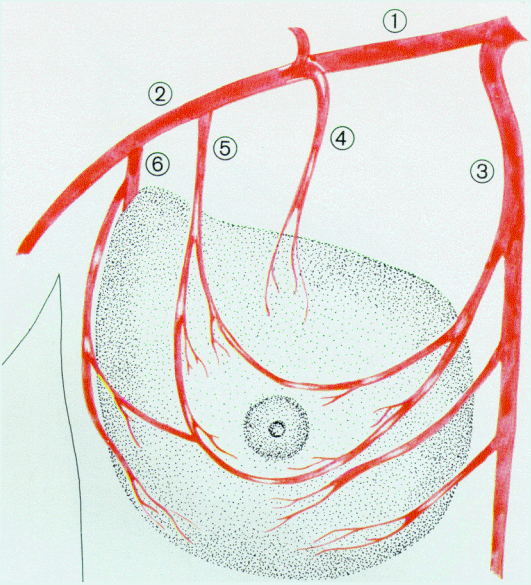


Fig. 22. *Scheme of the arterial breast vascularization.* From the subclavian (1) and axillary (2) arteries originate: the internal mammary artery (3) (medial peduncle): the thoraco-acromial artery (4) (middle peduncle); the external mammary (5) and the infrascapular artery (6) (lateral peduncle). The arterial branches originating from these peduncles form a peri-glandular vascular tree which is much more developed in the pre-glandular area where branches are fully anastomosed in areolar region. Therefore the half-deep position of the arterial main branches allows their C.T. demonstration. The cutaneous, subcutaneous and glandular vascularization depends on the arterial pre-glandular tree. Particularly, the branches directed to the parcnchyma follow the interlobar septa as far as the posterior wall is reached (see Fig. 23A). The vascularization of the retro-glandular fat tissue depends on the branches originating from the posterior glandular wall. Finally, the vasculaization to the deep muscular layers is partly dependent on the thin branches of the post-glandular tree, partly on the branches originating from the intercostal arteries which are not drawn on this scheme (see Fig. 23A).

course and a drainage which corresponds to the main pre-glandular arterial branches (true << arterio-venous peduncles»: Fig. 24); ii) the *superficial route,* originating from the peri-areolar ring and running in the skin layer, where it forms a tree much richer than the arterial one (Fig. 25).

a mammary angiogram in tangential view (Fig. 23B). The following vessels should be identified (Fig. 23 A): α) *a superficial vascular tree* for the skin layer, mainly from veins, included in the upper 3 mm; it has a reticular appearance, with large and variable meshes (Fig. 25A). This tree - partly recognizable during the inspection - can be well demonstrated by infra-red (I.R.) photography (Fig. 25B), with a pattern very si-

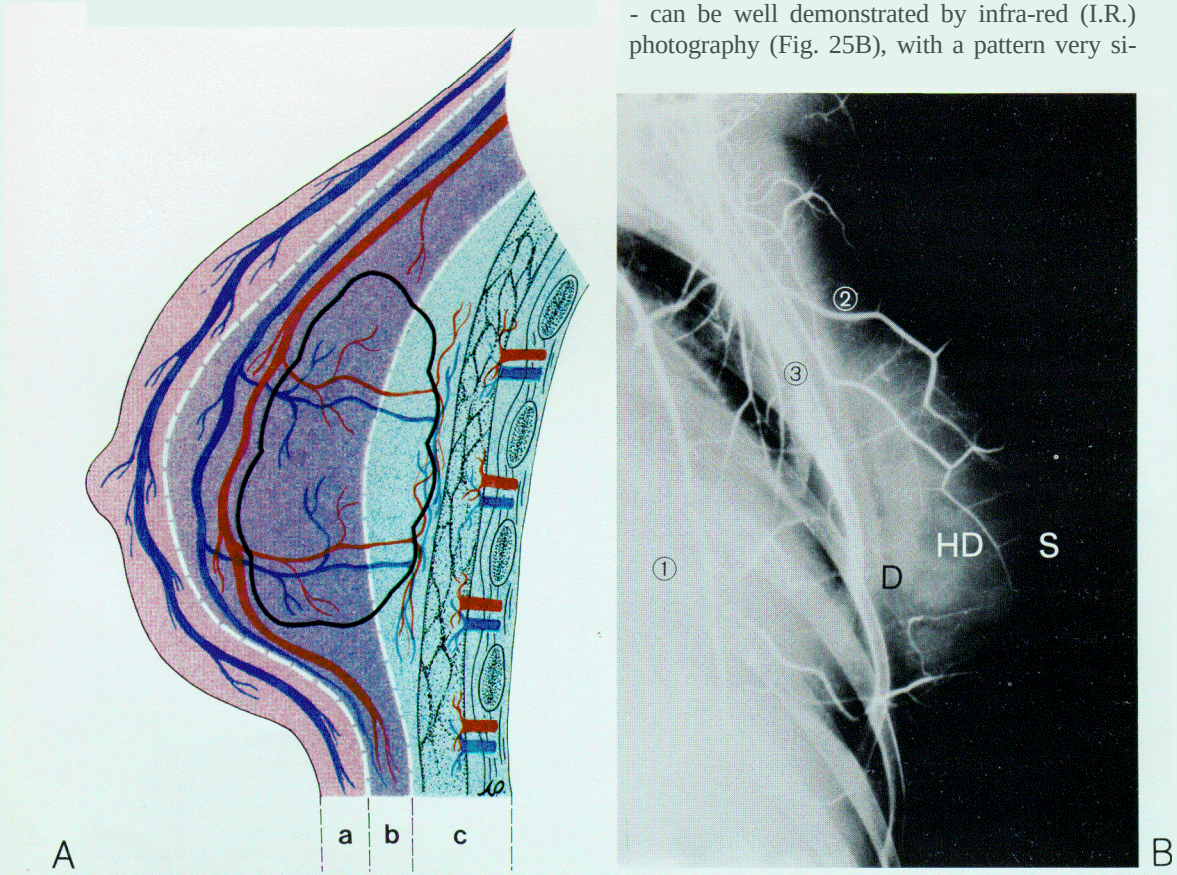


Fig. 23 A-B. *Spatial distribution of the mammary vascularization.* A) *Scheme of the distribution layers of the mammary vascularization* (breast sagittal section). a) *Superficial vascular tree*, mainly due to a venous origin; it is partially recognizable on inspection, but it is more visible when performing an infra-red (I.R.) photography. It is always demonstrated by C.T., superposed to the half-deep vascular tree. b) *Half-deep vascular tree*, formed by arterial and venous vessels. It is only recognizable by C.T., with better results after breast cooling, due to the constriction of the superficial vascular tree. c) *Deep vascular tree*, formed by arterial and venous vessels. It is not recognizable by C.T. B) *Breast angiography in tangential view.* Retrograde injection of the contrast medium through the brachial artery. The main branches arise from the internal mammary (1), from the external mammary (2), and the infrascapular artery (3) to form the peri-glandular tree. The poor cutaneous arterial supply (superficial vascular tree: S), and the prevailing pre-glandular arterial supply (half-deep vascular tree: HD) are confirmed; the retro-glandular arterial supply is very thin (deep vascular tree: D). Angiogram kindly supplied by Dr. RUFFATO.

b) The spatial distribution of the arterial and venous breast vascularization. It should be - as it has been schematically described - remembered in order to interprete exactly the CT. pattern (Fig. 23 A). In the attempt of explaining such a spatial distribution it is useful to refer to

milar to that presented by C.T., particularly when the breast presents venous engorgement (pregnancy, lactation);[36, 56, 57, 81] β) *a half-deep urterio-venous vascular tree* directed to the subcutaneous and glandular structures (Fig. 24): none of these vascular structures is visible at

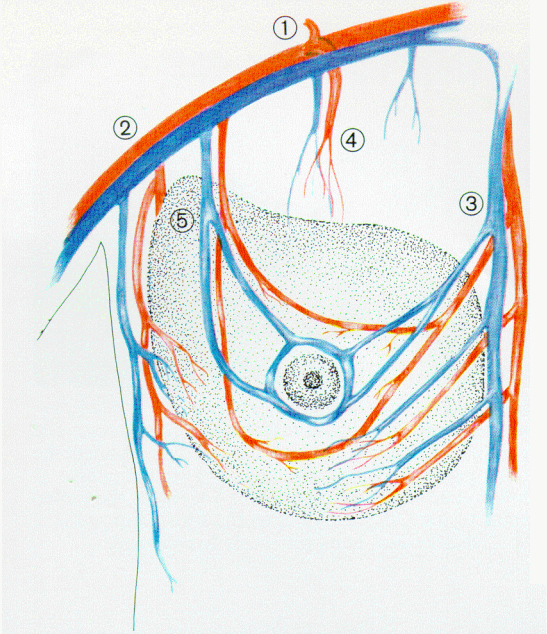
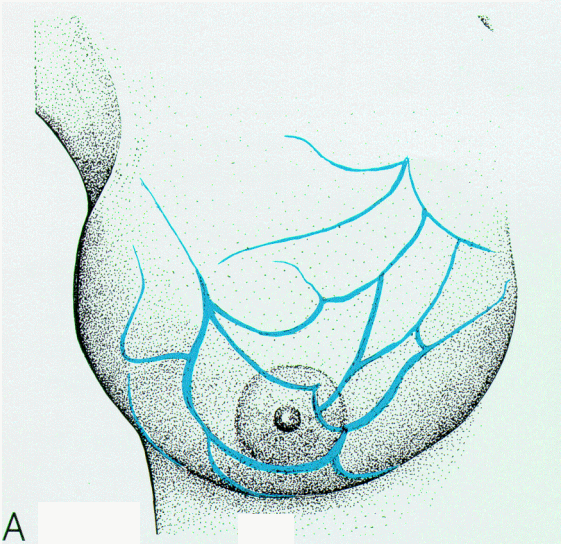


Fig. 24. *Scheme of the breast venous vascularization.* The half-deep venous drainage originates from the rich peri-areolar ring and then follows the course of the arterial main branches. Therefore, these veins are in pre-glandular position. Their flow reaches the subclavian (1) and the axillary (2) veins. The C.T. pattern of the half-deep vascularization is formed by both arterial and venous components, usually not differentiated (arterio-venous medial (3), middle (4) and lateral (5) peduncles)

the inspection, neither by I.R. photography. C.T. is able, on the contrary, to analyse the half-deep arterio-venous pre-glandular distribution about 15 mm from the skin surface; [34] γ) a deep *arterio-venous vascular tree:* these vascular structures can never be analysed by C.T. (Fig. **23).**

2. C.T. vascular pattern. The vascular tree can be analysed by CT. because of the temperature difference between the relatively hyperthermic vessels and the hypothermic breast background (II, B, 1, a). The C.T. vascular pattern is composed of the association of half-deep arterio-venous peduncles and of the superficial subcutaneous vascular tree (essentially venous).[34, 66, 85, 89] A typical reticular pattern characterizes the latter vascular tree. On the contrary, C.T. is not able to differentiate between arteries and veins of the half-deep vascular structures.

a) Origin. The main vascular branches (peduncles) which are identified on the C.T. breast pattern of women of fertile age,[34, 85, 89] are represented by: α) *medial* peduncle (internal arterio-venous mammary system: Fig. 26); β) *lateral peduncle* (external arterio-venous mammary system: Fig. 27); γ) *inferior branch of*



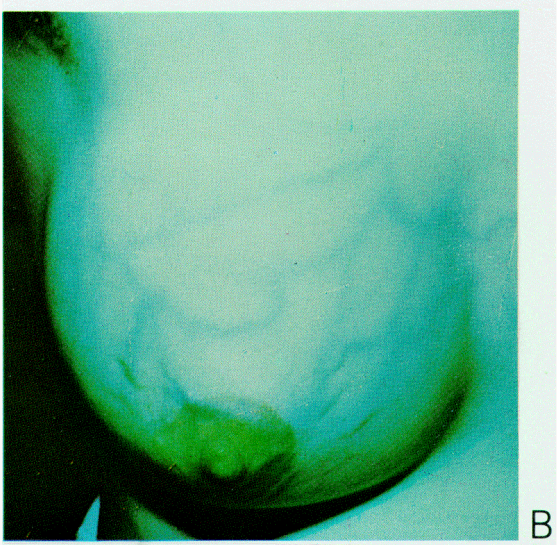


Fig. 25 A-B. A) *Scheme of the breast venous vascularization* (drawn from the Fig. 25B: I.R. photography). The superficial vascularization shows a regular «crossing-like» pattern on the skin. The arterial vascularization is much thinner and widespread. Therefore, the C.T. pattern of the superficial vascularization is mainly due to the venous component. B) *I.R. photography.* The venous skin pattern is also recognizable on inspection, particularly when conditions of engorgment (pregnancy, lactation) are present. The I.R. photography allows the optimal demonstration.

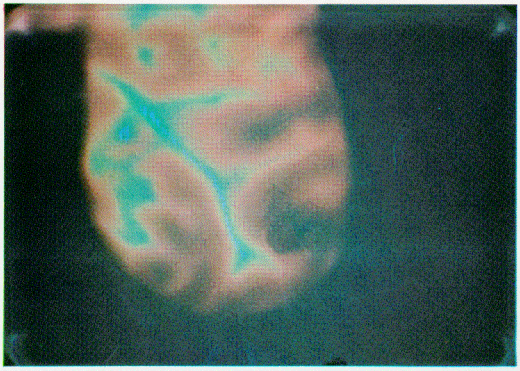
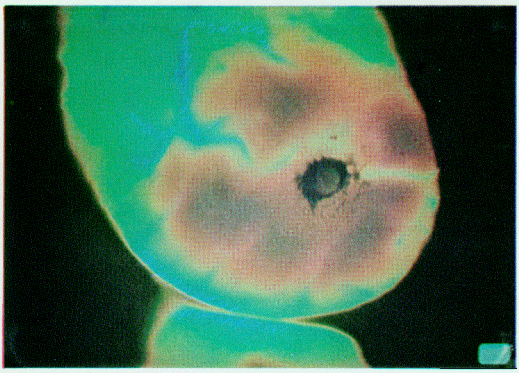


Fig. 26. Normal case, left breast, frontal view. *Vascularization*: the medial peduncle with its main branch and its secondary branches is well recognizable. *Nipple*: hypothermic, with sharp borders. Background: homogeneously hypothermic.



Pig. 27. Normal case; right breast; lateral view. Vascularization: the lateral peduncle is well recognizable. Two main branches with thin secondary branches originate from it. *Nipple:* hypothermic, with sharp borders. Backgroundl: homogeneously hypothermic: the breast inferior edge is hyperthermic (infra-mammary sulcus).

Fig. 28. *Normal case*; right breast; lateral view. *Vascularization*: the lateral peduncle is squat, with short main branches; the inferior branch of the lateral peduncle is well represented and reaches the nipple with a transversal course. *Nipple*: not visible (marker point). *Background*: homogeneously hypothermic.

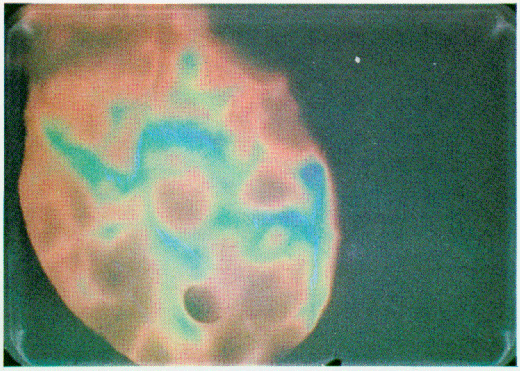


Fig. 29. *Normal case*; left breast; frontal view. *Vascularization*: uniformly distributed vascular tree (2nd grade). The medial and the lateral peduncles are well represented; the middle peduncle is thin, tortuous, with vertical course. A marked transversal anastomosis is visible in the supra-areolar region. *Nipple*: hypothermic, with sharp borders. Back,ground: homogeneously hypothermic.

the lateral peduncle, smaller, not always recognizable (arterio-venous infrascapular system: Fig. 28); 6) *middle peduncle,* which is also not always recognizable (arterio-venous thoraco-acromial system: Fig. 29). These peduncles (and their main collateral branches) have usually a reciprocal balance: the dominance of a peduncie (Fig. 77) is accompanied by a lesser development of the other ones.[7, 85, 89]

b) Distribution and anastomoses. The peduncles divide themselves into main branches, variable in number, with radiate disposition towards the areola (Fig. 30) and with smooth loops. Among the regions vascularized by the peduncles, some anastomoses can be found, the most important of which is named superior communicating vessel (Figs. 31, 89) characterized by a transversal course and a supra-areolar position.[68, 85]

c) Diameter. The diameter of the peduncles and of their main branches progressively decreases towards the areolar region (Fig. 27), because of the origin of the secondary branches.[34, 85]

d) Secondary branches. They arise from the main branches at acute angles; their course is usually short; their diameter is regular, narrower than the diameter of their source (Fig. 26).

e) Terminal branches. The distal part of the main branches decreases towards the nipple with «tapered» pattern (Fig. 27). Sometimes a sharp «cut-off» of the main branch can be re-

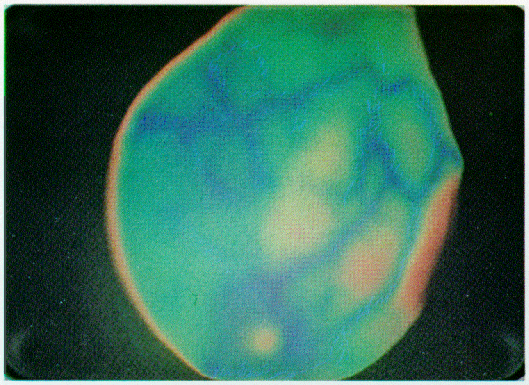


Fig. 30. *Normal case*; right breast; frontal view. *Vascularization*: there is a marked medial peduncle with some marked main branches reaching the nipple where a peri-areolar ring is visible. Many anastomoses with the lateral peduncle (3rd grade). *Nipple*: slightly hyperthermic, with sharp borders. *Background*: homogeneously and slightly hyperthermic. The slight hyperthermia of the nipple and of the background depends on the marked vascular tree. In this case the «preliminary cooling» could be useful.

Fig. 31. *Normal case*; right breast; frontal view. *Vascularization*: there is a marked transversal anastomosis, with tortuous course, and uniform diameter (superior communicating vessel). *Nipple*: hypothermic, with sharp borders. *Background*: homogeneously hypothermic.

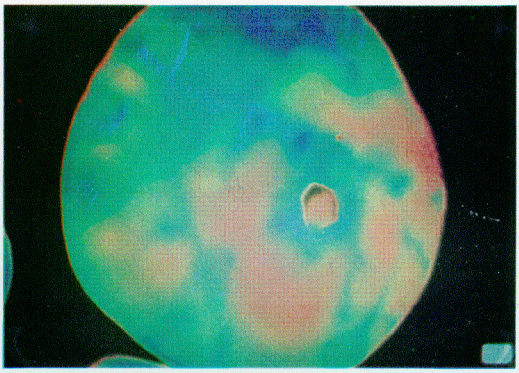


Fig. 32. *Normal case*; left breast; frontal view. *Vascularization*: the main branch of the marked medial peduncle reaches the marked peri-areolar ring. *Nipple*: hypothermic, with sharp borders. *Background*: homogeneously hypothermic.

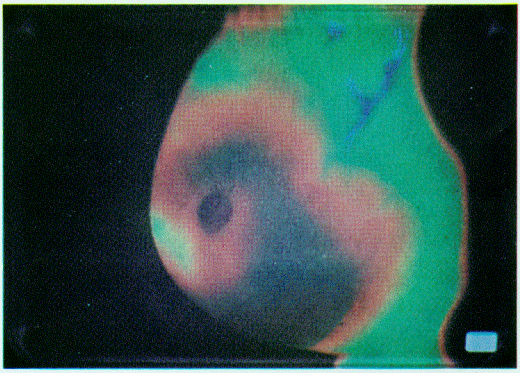


Fig. 33. *Normal case*; left breast; lateral view. *Vascularization*: lateral peduncle very thin with short main branch (1st grade). *Nipple*: hypothermic, with sharp borders. *Background*: homogeneously hypothermic.

cognized in proximal position, usually caused by a sudden angulation and intra-glandular distribution [89] (Figs. 23 A, 28). This finding mimics a real vascular «cut-off» and its interpretation can be difficult (III, A, 3, c, α, iii). The terminal branches anastomose each other to form a mainly venous peri-areolar ring [34, 85, 89] located around the nipple (Figs. 30, 32).

f) Grades of vascularization. The normal woman breast presents some discrete variation of its vascularization: [2, 22, 23, 34, 41, 65, 78, 82, 85, 86, 88]

α) *1st grade* (Fig. 33): the peduncles are slightly outlined; there are few main branches hypothermic; the peri-areolar ring is not visible or faintly recognizable. The 1st grade vascularization (about 15 per cent of females) is recognized in: i) *pre-puberty and post-menopause* (low hormonal rate, particularly progesterone); ii) *para-physiological conditions*: underdeveloped or fat breast; iii) *male normal breast*; β) *2nd grade* (Fig. 29): the peduncles divide into 2-3 main branches, directed towards the nipple, often presenting anastomoses (superior communicating vessel); the secondary branches arise regularly spaced from the main branch; the peri-areolar ring is usually recognizable. The 2nd grade vascularization (about 65 per cent of females) is the most frequent pattern of the fer-

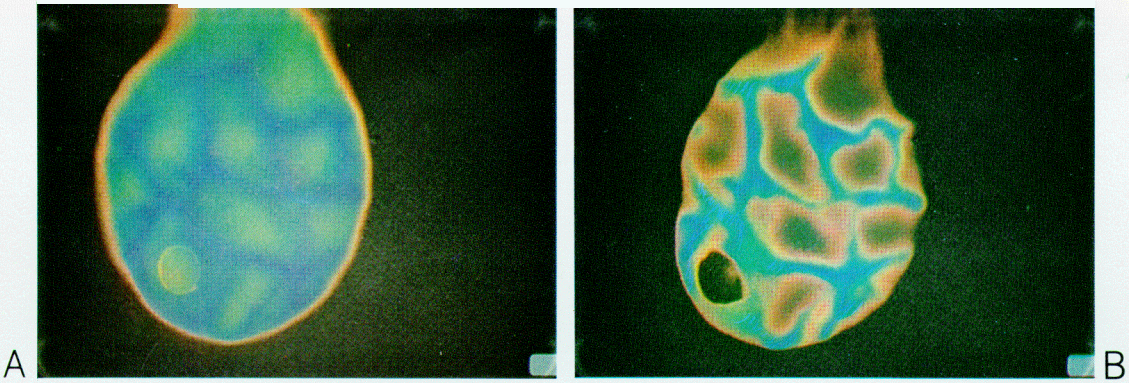


Fig. 34 A-B. *Lactation*; right breast; frontal view. A) *Basal conditions* (without «preliminary cooling»). *Vascularization*: the lateral, middle and medial peduncles are marked with uniformly increased diameter, and main branches richly anastomosed. Marked peri-areolar ring. *Nipple*: hyperthermic. *Background*: homogeneously and markedly hyperthermic. B) *After preliminary cooling. Vascularization*: unchanged distribution, the vascular tree presents a reduced and well defined diameter. *Nipple*: hypothermic, with sharp borders. *Background*: homogeneously hypothermic.

tile age and remains unchanged for some years after the menopause. It corresponds to the C.T. standard pattern, already mentioned; y) 3rd *grade* (Fig. 30): the lateral and medial peduncles are very large; the middle peduncle and the inferior branch of the lateral peduncle (not always present in the 2nd grade) are almost always recognizable. There is a great number of main branches, with wide diameter and with less important terminal tapering; there are many secondary branches of increased length, and with smooth loops. Large anastomoses are present in full calibre and at variable angles. The peri-areolar ring is very marked. Because of the rich vascularization, the mammary background is less hypothermic (III, C, 1, a). The 3rd grade (as the 4th grade, too) needs the <<preliminary cooling)) (II, B, 1, e, a) in order to increase the temperature difference between vessels and breast background. The 3rd grade vascularization (about 15 per cent of females) is found in women who have high hormonal rates (pregnancy, longstanding contraception); it is exceptionally found in menopausal women; 8) *4th* grade (Figs. 34,78): the breast is crossed by a wide vascular tree, with remarkably increased diameters. The mammary background is hyperthermic: the <<preliminary cooling)) and the plate 34 with higher <<lower thermal level)) (I, C, 2, b) are usually utilized. The 4th grade vascularization occurs when there is highly increased endocrine activity (end of pregnancy or lactation).

g) Breast thermo-vascular asymmetry. In normal conditions, the mammary vascularization and background are usually symmetrical in both mammae.[3, 22, 23, 25, 33, 65, 78] The causes of a relative thermo-vascular increase in one mamma are: *a) morphological:* the bigger mamma, when there is a volume asymmetry; p) *structural:* the mamma richer in glandular tissue, when there is an asymmetry of glandular growth; y) *vascular:* the most vascularized mamma, when there are asymmetries in the subcutaneous venous circulation.

3. Abnormalities of CT. *VaSCUlar* pattern.

The abnormalities of vascularization are the most important element for analysing the C.T. breast patterns. Different kinds of vascular changes being possible, the association of two or more of them is very often encountered. Nevertheless, it is preferable for teaching aims, to give the description of the single vascular elementary changes (course, diameter, morphology, extension).

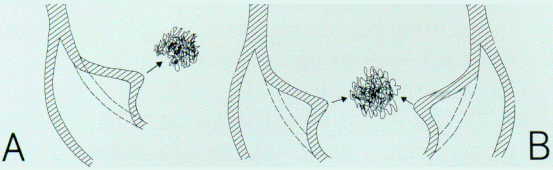


Fig. 35 A-B. *Scheme of the vascular traction.* A) Traction on a single vessel. B) Traction on two contiguous vessels.

a) Changes of the vascular course. They can be encountered either at the peduncle level or at the main branch level. Secondary and terminal branches are more seldom involved. Two pathogenetic modalities can be assumed:

α) *traction.* The vessels can be stretched by retracting processes, due to a scar (sequelae of mastitis, or of surgical intervention or of radiation therapy) or to a neoplastic lesion (mainly scirrhous).[34, 47, 59, 66, 69, 84, 85, 87, 89] It is very important to recognize the number of the vessels involved by the retracting process: i) *traction on a single vessel* (Fig. 35 A): this finding is usually caused by a benign process as just mentioned (Fig. 36); ii) *traction involving several contiguous vessels* (Fig. 35 B), sometimes originating from different peduncles: the stretched vessels can converge towards a central zone (Fig. 37) forming a «pseudo-star» image (III, A, 3, b, γ, iii). This finding should suggest a possible malignant lesion to be present (Fig. 53). The findings defined as «captation» and described by French Authors will be further illustrated;

β) *compression.* The vessels can be compressed by <<space occupying non infiltrating lesions)) (solitary or multiple cystes, fibroadenomas, hematomas, chronic abscesses). The vascular print characteristics give very useful information about the size and the number of the

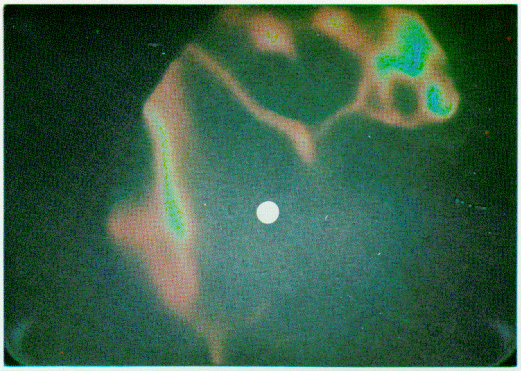


Fig. 37. *Mastitis sequelae*; left breast; frontal view. *Vascularization*: main branches of the medial peduncle tilted towards the nipple, with uniformly reduced diameter and straight course. *Nipple*: not visible (marker point). *Background*: homogeneously hypothermic.

«space occupying lesions»:[69, 84, 85, 86, 87, 88] i) *single impression* (single mass: Fig. 38 A): when a single vessel is impressed, the impression entity depends on the mass size (Fig. 39); when two contiguous vessels are impressed (Fig. 38 B) they present a «cup-like» configuration (Fig. 40); ii) *multiple contiguous impressions* (fibrocystic disease): in this case there are several vascular impressions with narrow prints (Fig. 38 C), involving one or more vessels.[85] When the impressions are in very close connection, the vessel presents a «cork-screw-like» pattern (Fig. 41).

b) Changes of the vessels diameter. The vascular diameter can be increased or decreased. Different pathogenetic modalities correspond to these modifications. An increase vascular diameter is indicative of an increased arterial flow and an increased venous drainage. The decreased vascular diameter depends on a decreased arterial flow or can be due to local causes (compression or traction).

Fig. 36. Mastitis sequelae right breast: lateral view. *Vascularization*: squat lateral pedluncle with short main branches: the inferiorbranch ofthc lateral pedunclepresents a slightly increased diameter with straight course. tilted towards the nipple. Nipple: hypothermic, with sharp borders. *Back*. ground homogeneously hypothermic.

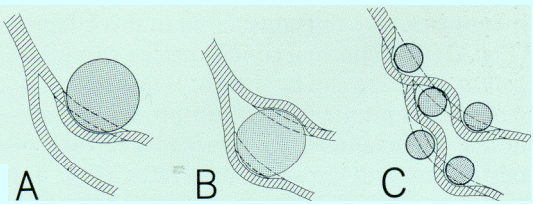


Fig. 38A-B-C. *Scheme of the vascular compression.* A) Impression by a single mass on a single vessel. B) Impression by a single mass on two contiguous vessels. C) Impressions by multiple contiguous masses.

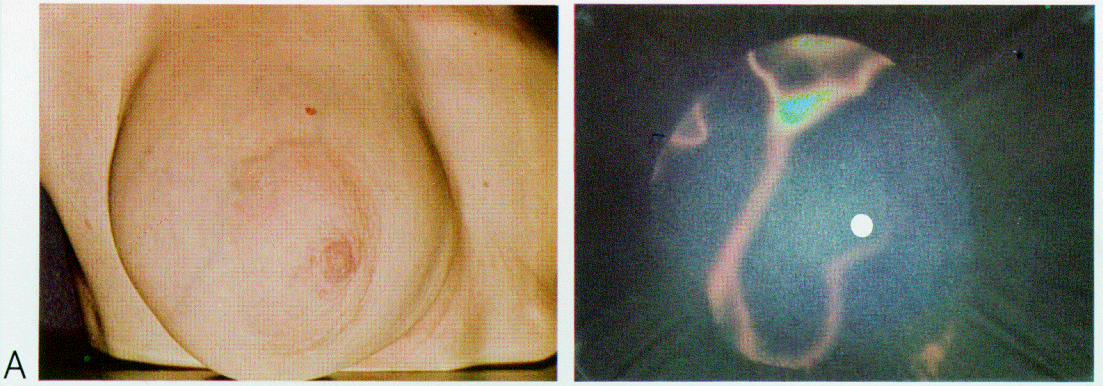


Fig. 39 A-B. *Fibro-adeno-lipoma* of the upper-lateral quadrant; right breast; frontal view. A) *Physical examination.* B) *C.T. pattern. Vascularization*: long main branch of the middle peduncle with vertical course, laterally shifted and reduced in diameter because of the compression from the large mass. *Nipple*: not visible (marker point). *Background*: homogeneously hypothermic.

Fig. 40. *Large solitary cyst* in the lower-medial quadrant; left breast; frontal view. *Vascularization*: squat medial peduncle; smooth impression on the two main branches which are spreaded with a «cup-like» pattern; their diameter is slightly reduced by the compression. *Nipple*: not visible (marker point). *Background*: hypothermic oval shaped area in the cyst's site.

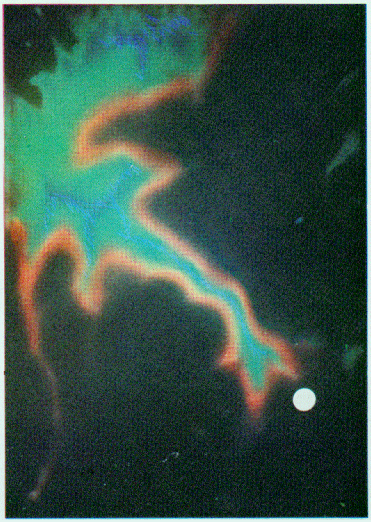


Fig. 41. *Fibrocystic disease*; right breast; lateral view. *Vascularization*: the lateral peduncle and its main branch present a markedly increased diameter and multiple small impressions («cork-screw-like» pattern); there are also some terminal «spicules». *Nipple*: not visible (marker point). *Background*: homogeneously and markedly hypothermic.

a) Decreased vascular diameter. The individual variations, like poor mammary vascularization (Fig. 33) (III, A, 2, f, a) or progressive reduction of the vascular diameter during the menopause, are not considered in this chapter (Fig. 42). In abnormal conditions the vascularization decrease can be due to: i) *hormonal imbalance:* in pituitary prolactin producing adenoma, for example, the marked decrease of oestrogens and progesterone rates (Fig. 43) causes - other than background temperature decrease (III, C, 2, c, r) - a remarkable reduction of the mammary vascular tree (Fig. 44) and the disappearance of the normal vascular thanges during the menstrual cycle; [1] ii) *mastosis:* in spite of the hyper-oestrogenic situation (which causes an increase of the vascular tree: III, A, 3, b, p, i) it is sometimes possible to observe a marked decrease of the mammary vascularization, due to the prevalent fibrotic involution which makes the gland non responsive to the hormonal stimuli (Fig. 45); iii) some conditions determining C.T. patterns of traction (particularly due to *scar and post-operative fi-*

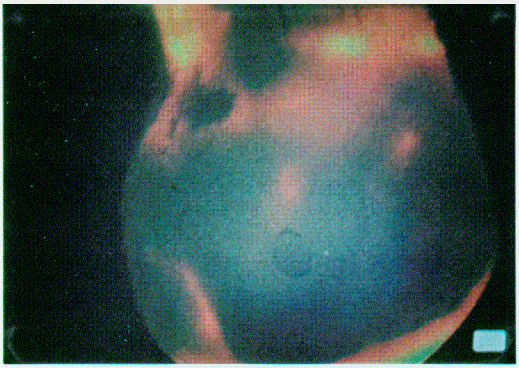


Fig. 42. *Menopause*; right breast; lateral view. *Vascularization*: linear vascular structures with well defined aspects are not visible. Nipple hypothermic. with sharp borders. Background: homogeneously and markedly hypothermic.

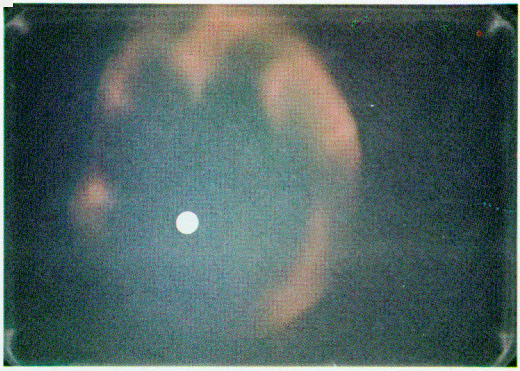


Fig. 44. *Galactorrhoea in prolactin producing pituitary adenoma*; left breast; frontal view. *Vascularization*: the lateral peduncle is jusi recognizable at its origin. The rest of the: vascular tree is absent. Nipple: not visible (marker point). Background: homogeneously and markedly hypothermic.

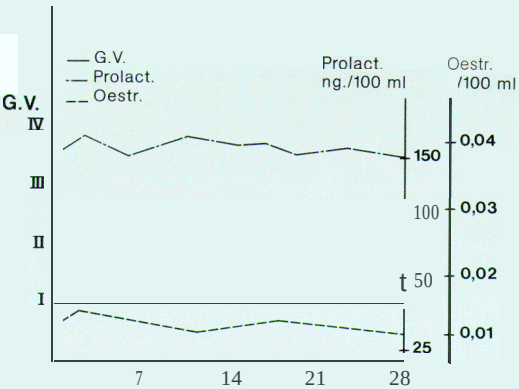


Fig. 43. *Prolactin producing pituitary adenoma.* The prolactin level (Prolact.) is greatly increased; the oestrogens level (Oestr.) is very low, without cyclic variation. The breast vascularization (G.V.) is a 1st grade type, and does not present any cyclic variation.

Fig. 45. *Localized mastosis* of the upper-medial quadrant; left breast; frontal view. *Vascularization*: the main branches of the medial peduncle appear squat, tortuous, with «spicules» of their secondary and terminal branches. *Nipple*: not visible (marker point). *Background*: homogeneously hypothermic.

brosis: Fig. 37), and of impression (particularly due to single *benign mass*: Fig. 39B), are often associated with a decreased vascular diameter.[85, 86, 88] In the extreme situations the vessel can be completely flattened with disappearance of its lumen; iiii) all conditions determining a thickening of the skin surface (*fibrosis following radiation therapy*: Fig. 91) or oedema of the glandular and para-glandular tissues (*peritumoural oedema*: Figs. 86B, 88B) can cause a marked decrease of the vascular tree; when it is recognizable, it presents ill-defined borders.

β) *Increased vascular diameter with normal course of the vascular tree.* The increased vascular flow can be caused by the following mammary lesions: i) *mastosis*[23, 85, 89] (the relative or absolute hyper-oestrinism, causes a glandular hyperplasia with a related increased arterial flow: Figs. 46, 57, 59, 60, 64, 67, 69, 70, 72, 73, 74); ii) *acute inflammation* of diffuse type (mastitis: Fig. 47) or localized type[23, 60, 69, 84, 85, 88] (abscess: Fig. 82A). In these situations the vascular tree does not usually present important abnormalities of its course.

γ) *Increased vascular diameter with abnormal course of the vascular tree.* This pattern is typical of the malignant lesions. From the hemodynamic point of view, the neoplastic lesion

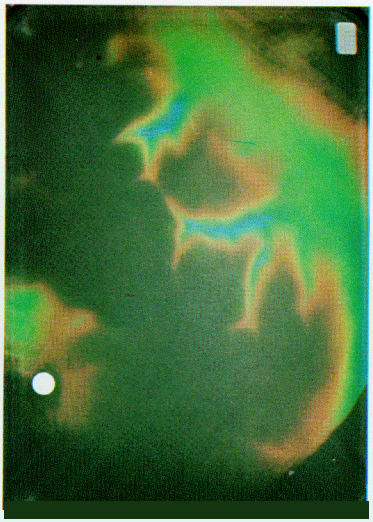


Fig. 46. Localized mastosis of the upper-lateral quadrant; left breast; lateral view. Vasculaizartion: the main branches of the lateral peduncle have tortuous course and moderately increased diameter; the terminal branches have <<crescent-liken and <<spiculex pattern. Nipple: not visible (marker point). *Background:* homogeneously hypothermic.

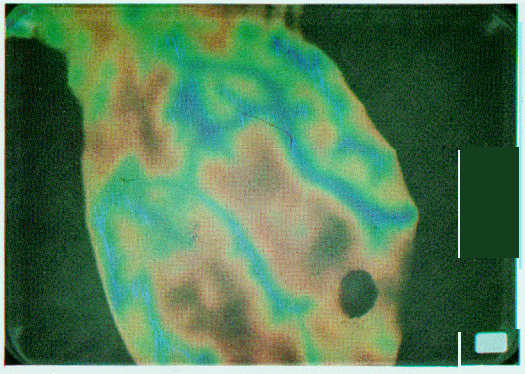


Fig. 47. *Acute mastitis*; left breast; frontal view. *Vascularization*: the vascular tree is diffusely and markedly enlarged, without abnormalities of course and morphology. *Nipple*: hypothermic, with sharp borders. *Background*: moderate hyperthermia in the region of the lateral peduncle.

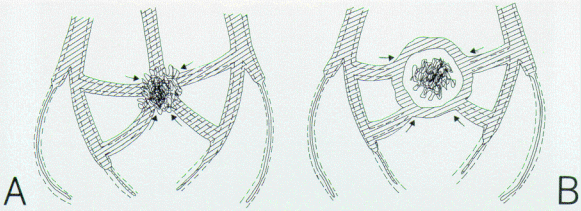


Fig. 48 A-B. *Scheme of the tumoural vascular neoformation.* A) *Tumoural star*: this is a marked dilatation of the arteries supplying and of the veins draining the tumoural arterio-venous fistula. The vessels not affected by the tumoural vascularization present a decrease of their diameter, due to the reduced blood-flow (blood shunt towards the tumour). B) *Peri-tumoural vascular ring*: the vascular neoformation surrounds the tumoural mass.

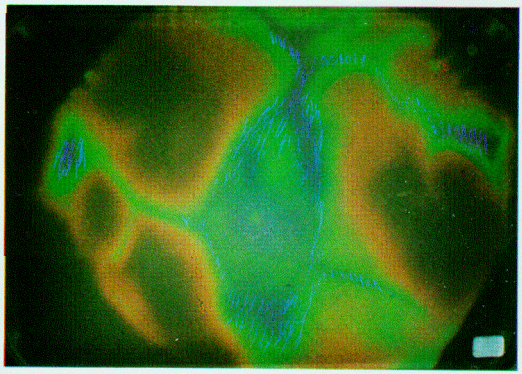


Fig. 49. *Intra-canalicular carcinoma behind the areola*; left breast; frontal view. Vasculanzation: very enlarged vessels with abnormal course converge to form a <<tumoural star>> which corresponds to the tumour. Nipple: slightly hyperthermic. *Background:* large hyperthermic areolar area which includes the vessels with abnormal course and the nipple.

acts as an arterio-venous fistula, because of the disappearance of the capillary barrier within the intra-tumoural neo-vascularization (Fig. 48). The enlargement of the supplying arteries and of the draining veins is a basic sign in any angiographic pattern of malignant tumours, wherever located. The remarkable blood supply to the tumoural mass and the related venous drainage cause the typical vessel enlargement and even neo-vascularization (Figs. 80B, 81) which could be not appreciated in normal conditions, either by angiography or by C.T.[20, 52, 53, 71, 72, 84]

i) The vascular enlargement involves all vessels close to the tumour, producing the typical C.T. pattern described as a *tumoural star*.[31, 34, 47, 49, 50, 52, 59, 61, 66, 75, 76, 84] This pattern is composed by very enlarged vessels converging with abnormal course towards the tumour: Figs. 48A, 49, 50, 51, 52). In the French literature this pattern is called cuptation.[82, 84, 85, 86, 87, 88] The word «captation» describes very well the C.T. pattern but it can be misunderstood suggesting a vascular <<traction>> on vessels remotely located from the tu-

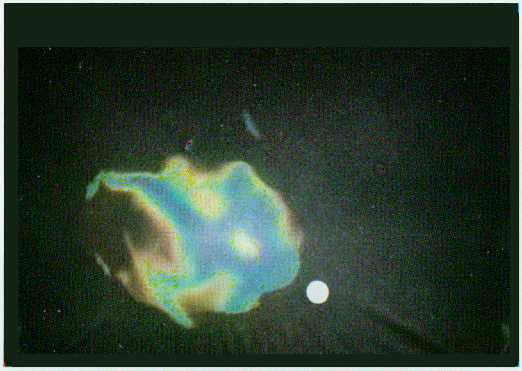


Fig. 50. *Diffuse sarcoma* of the lateral quadrants; right breast; lateral view. *Vascularization*: markedly enlarged vessels have abnormal course and converge towards the tumour («tumoural star»). *Nipple*: not visible (marker point). *Background*: irregular hyperthermic area in the zone of vessels convergence.

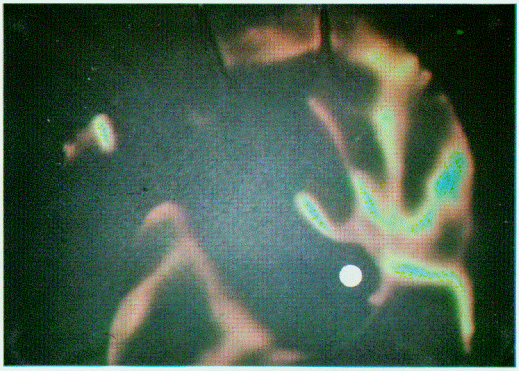


Fig. 51. *Carcinoma* in the upper-medial quadrant; right breast; frontal view. *Vascularization*: «tumoural star» formed by the branches of the middle and medial peduncles, which present an increased diameter and a straight course. *Nipple*: not visible (marker point). *Background*: «hot spot» in the centre of the «tumoural star».

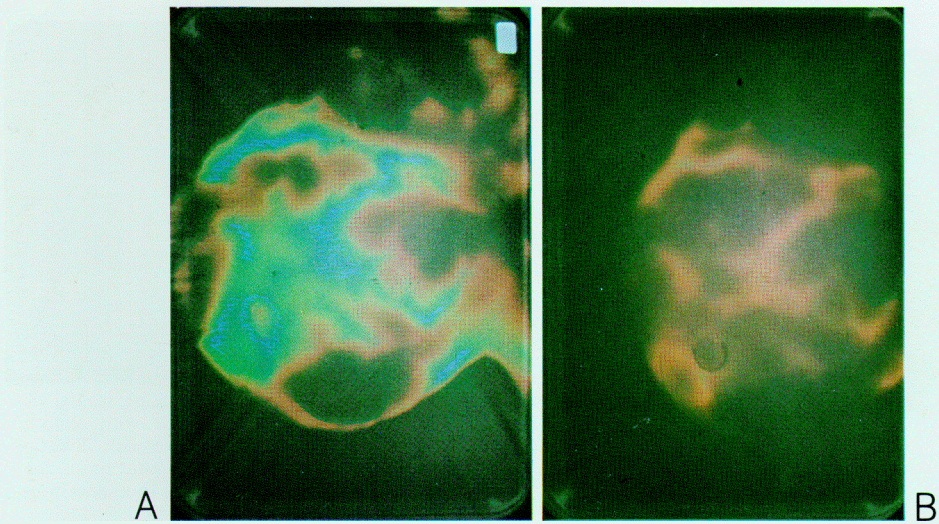


Fig. 52 A-B. *Carcinoma* of the lower-lateral quadrant; left breast; lateral view. A) *Plate 33. Vascularization*: markedly enlarged main branches of the lateral peduncle, with abnormal course, converging to form a «tumoural star», placed laterally to the areolar region. *Nipple*: moderately hyperthermic, with well represented peri-areolar ring. *Background*: ill-defined markedly hyperthermic area in the zone of vascular convergence. B) *Plate 34*. The serial use of the plates permits the best visualization of the «tumoural star», due to the elimination of the lowest T values, corresponding to the background (see Fig. 14).

mour. In reality, it refers to pre-existing vessels with normal course, which become recognizable because of the enlargement caused by the tumoural hemodynamics. It is quite possible that, in scirrhous carcinomas - with poor blood supply and dominant fibrosis: Fig. 53 - there exists a true vascular traction towards the tumoural mass (III, A, 3, a, α, ii). The differential diagnosis between the vascular traction towards the tumour (((pseudo-tumoural star>>) and the true <<tumoural star>> caused by an increased blood flow should be based on the diameter of the involved vessels. The vascular diameter is normal or slightly increased in the traction <<pseudo-star)) (Fig. 53) while is markedly increased in the <<tumoural star>> (Fig. 49).

ii) Sometimes, the enlarged peri-tumoural vessels form a vascular *ring* (Fig. 48B) around the tumour.[31, 34, 47, 50, 52, 60, 61, 66, 69, 75, 76, 84, 85, 87, 88]

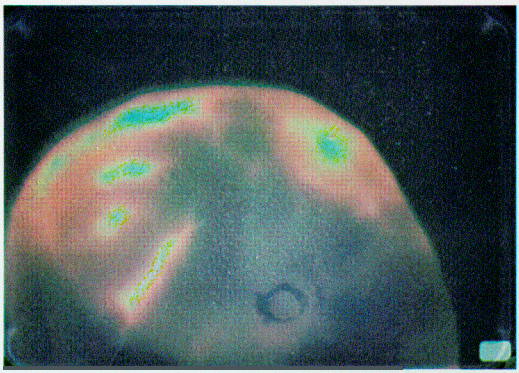


Fig. 53. Carcinoma with extensive fibrosis; right breast; lateral view. Vascularization: the main branches of the peduncles are converging towards the tumoural area boundaries, where they present a <<cut-off>> pattern. *Nipple:* hypothermic, with sharp borders. *Background:* large hypothermic area (fibrosis) corresponding to the tumour; the remaining background is slightly hyperthermic.

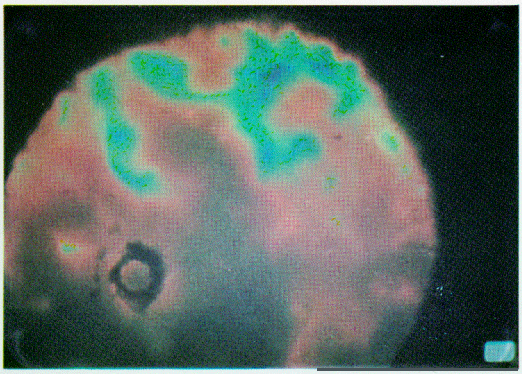


Fig. 55. Carcinoma of the upper-lateral quadrant; left breast; lateral view. Vasculization: the branches of the medial and lateral peduncles are slightly increased in diameter, with abnormal course according to an incomplete <<vascular ring)). *Nipple:* hypothermic, with sharp borders. *Background:* homogeneously hypothermic

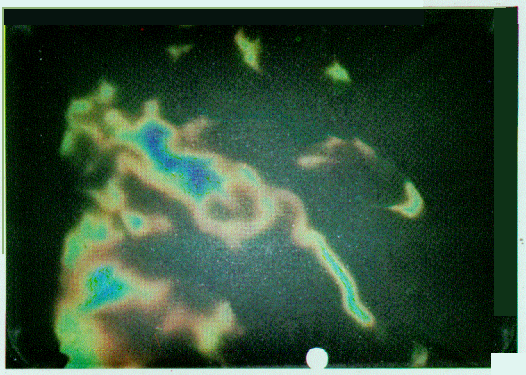


Fig. 54. Carcinoma of the upper-medial quadrant; left breast; frontal view. *Vascularization*: the main branch of the medial pcduoclc presents a very increased diameter, and joins the inferior branch of the lateral ,peduncle, presenting a complete «vascular ring» (increased flow to the tumoural arterio-venous fistula). *Nipple:* normally hypothermic. *Bnckground:* homogeneously hypothermic.

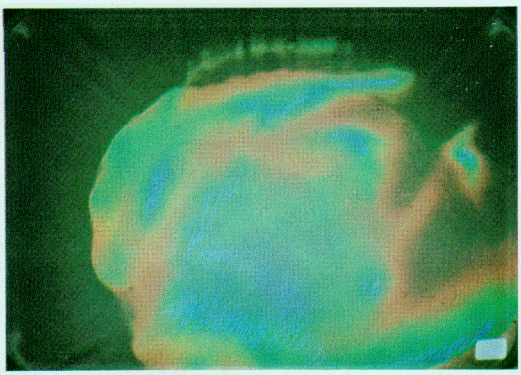
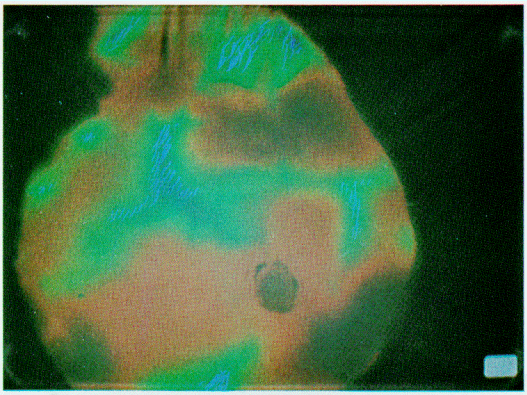
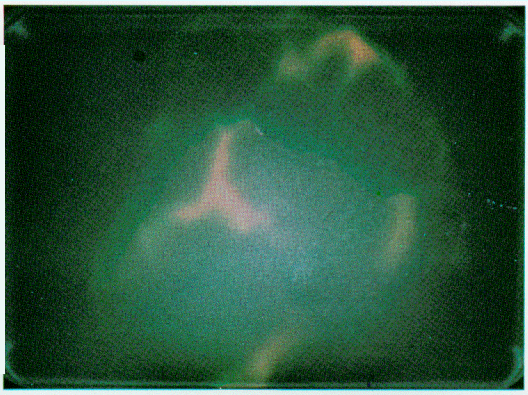


Fig. 56. *Carcinomatous mastitis*; right breast; frontal view. *Vascularization*: enlarged vascular tree with abnormal course. *Nipple*: markedly hyperthermic with ill-defined borders because of the marked areolar «hot spot». *Background*: diffusely hyperthermic with large «hot spot» in areolar and pcri-areolar region.

The «vascular ring» («boucle» of the French literature) can be complete (Fig. 54) or incomplete (Fig. 55). Either the «tumoural star» or the peri-tumoural «vascular ring» are typical of a malignancy. As the cancer growth rate is higher in well vascularized masses than in largely fibrotic masses, the neo-vascularization C.T. pattern has an important prognostic value.[4, 52, 68, 69, 71, 84, 85] Sometimes the peri-tumoural «vascular ring» or the «tumoural star» can be masked by the hyperthermic area («hot spot»: III, C, 2, b, α) corresponding to the tumour[50, 69, 84, 85] (Fig. 56); in such a case the vascular abnormality can be detected on the C.T. pattern only when the background hyperthermia has been eliminated by the «dynamic test» with cooling (II, B, 1, e, β): Fig. 52. When these vascular C.T. patterns are evaluated, the associated abnormalities should also be considered either those related to the mammary background («hot spot»: Fig. 92), or those of the nipple (hyperthermia: III, B, 2, a, β, iiiii) (Figs. 49, 52, 56). When these C.T. signs are associated with a space occupying lesion, they are highly suggestive of malignancy – even if clini-



A



B

Fig. 57 A-B. *Localized mastosis* of the upper-lateral quadrant; right breast; frontal view. A) *Basal conditions. Vascularization*: the main branch of the lateral peduncle is slightly enlarged, with tortuous course; the vascular bifurcation simulates a vascular convergence («pseudo-tumoural star»). *Nipple*: hypothermic, with sharp borders. *Background*: homogeneously hypothermic. B) *After «dynamic test» with cooling.* The elimination of the lowest T values permits the right interpretation of the «pseudo-tumoural star» (vascular bifurcation), due to the best definition of the vascular structures (see Fig. 14).

cal and mammographic examinations suggest a benign lesion - and biopsy is indicated.

iii) It should be remembered that some *pseudo-patterns of vascular abnormality* (which mimic a <<tumoural-star>> or a peri-tumoural ((vascular ring>>) can be encountered, due to a normal super-position of some of the main vascular branches. An important difference is given by the lack of other associated abnormalities. Moreover, the ((dynamic test>> with cooling can permit the identification of the single normal vascular structures[49, 60, 69, 84, 85] (Fig. 57). When there are some doubts, it should be necessary to follow-up the patient with another C.T. examination performed in The pre-ovulatory phase when the breast is least engorged[61, 84, 85, 87] nevertheless, when CT. pattern of «vascular ring» or of «tumoural star>> is confirmed, even without any other CT. or clinical-mammographic abnormality, the patient should be followed-up within 3 months.

c) Abnormalities of vascular morphology. Abnormalities of the vascular morphology are often associated with the two types of elementary vascular abnormality just mentioned (course and diameter abnormalities). A distinction has to be made - because of their different C.T. patterns - between morphological abnormalities of the peduncles and of the main branches, and those of the secondary and terminal branches.

a> Morphological abnormalities of the pe-

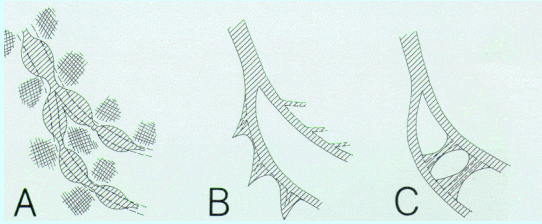


Fig. 58 A-B-C. *Scheme of the morphological vascular abnormalities.* Peduncles and main branches. A) «Beaded-like» pattern. Secondary branches. B) «Spicule» pattern. C) «Ladder-like» pattern.

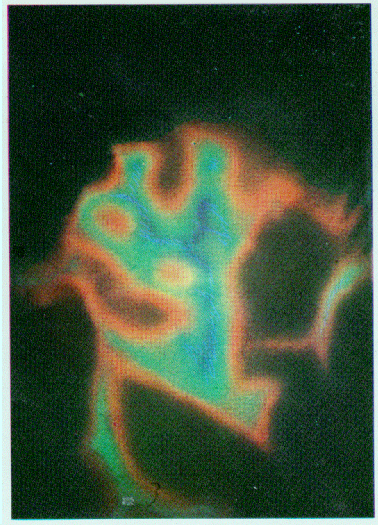


Fig. 59. *Localized mastosis* of the upper-lateral quadrant; left breast; lateral view. *Vascularization*: branch of the lateral peduncle with an increased diameter and with a «fragmentation» pattern. *Nipple*: not included in the image. *Background* homogeneously hypothermic

Fig. 60. *Localized mastosis* of the upper-medial quadrant; left breast; frontal view. *Vascularization*: the main branch of the medial peduncle presents an increased and irregular size («beaded-like» pattern) due to a series of alternate dilatation and narrowings. *Nipple*: not visible (marker point). Background homogeneously hypothermrc.

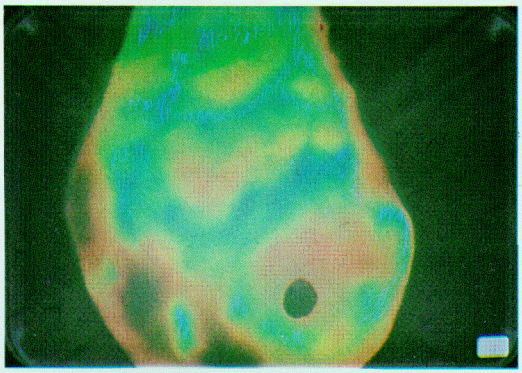


Fig. 61. *Chronic mastitis*; left breast; frontal view. *Vascularization*: there are some enlarged main branches and a double superior communicating vessel; they both present a course with many loops. *Nipple*: hypothermic, with sharp borders. *Background*: slightly and diffusely hyperthermic.

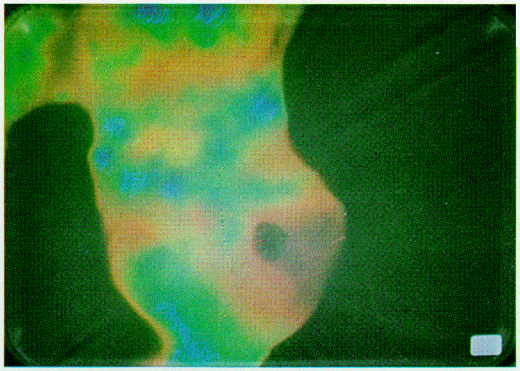


Fig. 62. *Carcinoma* of the upper-medial quadrant; left breast: frontal view. *Vascularization*: enlarged vessels with ((beaded-liken pattern, raising from the mcdial and middle peduncles, converge with abnormal course to form a pert-tumoural «vascular ring». *Nipple*: hypothermic, with sharp borders *Background* diffusely and moderately hyperther-mlc.

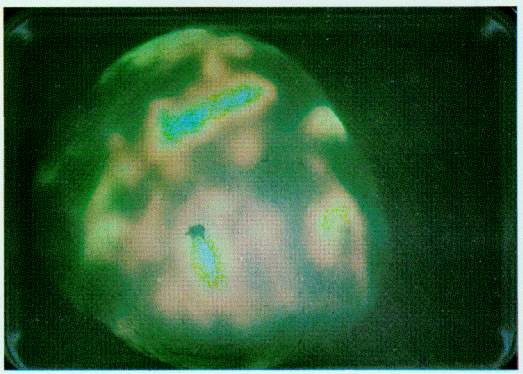


Fig. 63. *Neoplastic recurrence*, two years after radiation therapy; right breast; frontal view. *Vascularization*: enlarged vessels with abnormal course and «fragmentation» pattern. *Nipple*: hypothermic, with irregular borders (retraction). *Background*: moderately and not homogeneously hyperthermic.

duncles and of' the main branches. They are usually due to a series of alternate dilatations and narrowings *(beaded-like* pattern: Fig. 58A). Their extreme grade is represented by the vascular *fragmentation*[85, 89] (Figs. 59, 67, 91). Usually the <<beaded-like>> pattern is associated with the dilatation of the involved vessel. The vascular *cut-off* is more seldom encountered. The extent of the abnormality is variable: i) *beaded-like pattern of a single vessel* indicates a localized mastosis (Fig. 60); ii) *beaded-like pattern of several* main *branches* and/or of their corresponding peduncles: in this case, further signs should be taken into account for the clinical evaluation. The following situations should be considered: diffuse mastosis (concomitance of morphological abnormalities typical for the secondary and terminal branches: <<spicules>>, Fig. 64; ((ladder-like)) pattern: Fig. 65; III, A, 3, c, β, i, ii); mammary fibrotic healing (previous mastitis: Fig. 61; previous radiation therapy: Fig. 8.5; previous surgical treatment) when there are no clinical or C.T. suspicious signs; tumour (Fig. 62) or tumoural recurrence (following radiation the-

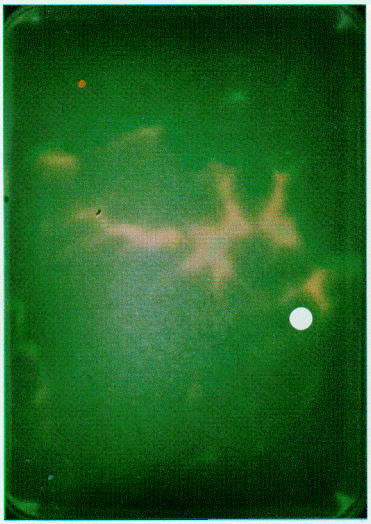


Fig. 64. *Localized mastosis* of the upper-lateral quadrant; right breast; lateral view. *Vascularization*: the main branch of the lateral peduncle is slightly enlarged, with tortuous course; the secondary branches have «spicule» pattern; the terminal branches have «crescent-like» pattern. *Nipple*: not visible (marker point). *Background*: homogeneously hypothermic.

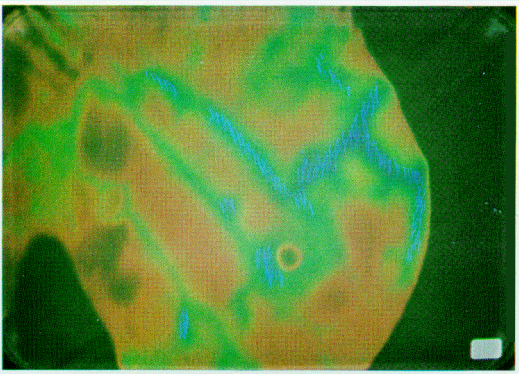


Fig. 65. *Diffuse mastosis*; right breast; frontal view. *Vascularization*: two main branches of the middle neduncle. with straight and parallel course towards the nipple, with short «spicules» of the secondary branches present a «ladder-like» pattern. Main branches of the lateral peduncle present enlarged diameter and tortuous course. *Nipple*: hypothermic, with sharp borders and peri-areolar ring. *Background*: homogeneously hypothermic.

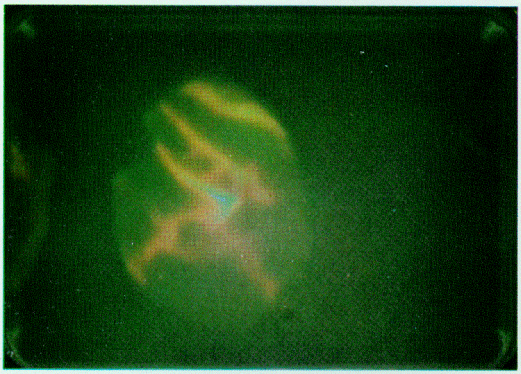


Fig. 66. *Localized mastosis* of the upper-medial quadrant. Left breast; frontal view. *Vascularization*: the branches of the medial peduncle, with slightly increased diameter, parallel each other, present short transversal connections («ladder-like» pattern). Close to the nipple a terminal branch forms a sudden, acute angle («sickle» shape). *Nipple*: hypothermic, with sharp borders and peri-areolar ring. *Background*: homogeneously hypothermic

rapy - Fig. 63 - or surgical treatment), when there are associated C.T. abnormalities of the nipple (III, B, 2, a, β) and of the background (III, C, 2, b, a, ii); in this case the borders of the vessels can be ill-defined (oedema) and sometimes fragmented;[68,69,84,85,89] iii) in the *vascular cut-off* the affected branch is sharply interrupted on the edge of a focal lesion, either due to a scar (fibrotic traction: Fig. 37) or to a cancer[47,50,59,66,69,84,85,87] (vascular infiltration: Fig. 53). Associated abnormalities (either of the vessels, or of the background and/or of the nipple) are extreme y necessary for a correct interpretation of such a C.T. pattern.

β) *Morphological abnormalities of the secondary branches.* The morphological abnormalities most frequently encountered are: i) *spicule* pattern (Fig. 58 B): dilatation of the secondary branch at its origin with progressive tapering of its terminal part (mastosis: Figs. 45, 64, 65, 67, 70, 74); ii) *ladder-like* pattern (Fig. 58 C), due to the anastomoses between «spicules» arising from two contiguous main branches (Figs. 65, 66). Both these patterns («spicule» and «ladder») can be localized or diffuse, in relation to the extent of the mastosic lesion.[85,89]

γ) *Morphological abnormalities of the terminal branches.* The following findings can be found: i) *spicule* pattern (Figs. 41, 46, 72), which is similar for the morphological and clinical significance to the «spicule» of the secondary branches (mastosis). The main branch itself frequently presents «spicules» either on its secondary branches, or on its terminal branch («bouquet» of the French literature:[84,85,89] (Fig. 67); ii) *club-like* or *ball-like*

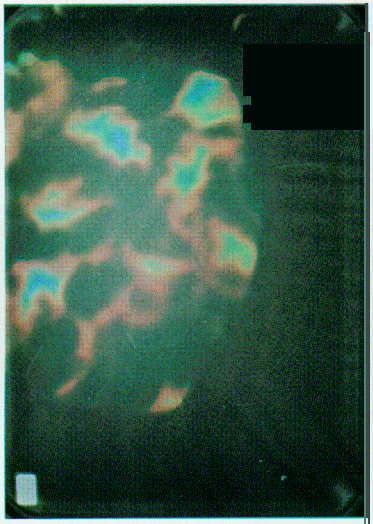


Fig. 67. *Diffuse mastosis*; right breast; lateral view. *Vascularization*: the vascular tree presents a diffuse enlargement, with «fragmentation» of the main branches; secondary and terminal branches have «spicule» pattern («en bouquet» mastosis). *Nipple*: hypothermic, with sharp borders. *Background*: homogeneously hypothermic.

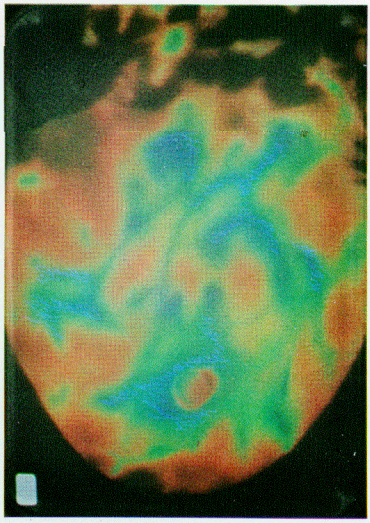


Fig. 69. *Diffuse mastosis with inflammatory changes*; right breast; lateral view. *Vascularization*: the vascular tree presents uniform and marked enlargement, and wide anastomoses. Some terminal branches present «club-like» and «ball-like» pattern. *Nipple*: hypothermic, with sharp borders, and marked peri-areolar ring. *Background*: homogeneously hypothermic.

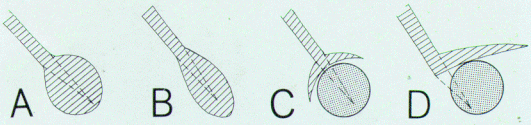


Fig. 68 A-B-C-D. *Scheme of the morphological vascular abnormalities*. Terminal branches. A) «Ball-like» pattern. B) «Club-like» pattern. C) «Crescent-like» pattern. D) «Sickle-like» pattern.

Fig. 70. *Localized mastosis* of the lateral quadrants; left breast; frontal view. *Vascularization*: the lower branch of the lateral peduncle presents a slightly increased diameter, with a straight course towards the nipple, and with its «club» shaped terminal branch; main branch of the middle peduncle with transversal course and secondary branches with «spicules». *Nipple*: hypothermic, with sharp borders. *Background*: homogeneously hypothermic.

pattern (Fig. 68 A-B): fusiform or rounded dilatation of the terminal branch.[50, 69, 84, 85, 89] It is very important to evaluate its size: moderate dilatations can be due to a mastosis (Figs. 69, 70, 96) while the widest dilatations, particularly when they are single, can be found in the cancer (Fig. 71). When associated abnormalities are missing, this finding is only presumptive. The largest dilatations of the terminal vascular branches can sometimes mimic an N hot spot>>. The vascular nature of the pseudo <<hot spot>> is easily recognizable by the ((dynamic test>> with cooling, due to the remarkable volume decrease of the vascular dilated terminal branch (vasoconstriction); iii) *Jyckle-like* and *crescent-like* pattern (Fig. 68 C-D):[85, 89] spatial abnormalities of the terminal branch, caused by traction (scar fibrosis) or by compression (space occupying non infiltrating lesions or fibrocystic diseases: Figs. 46, 64, 66, 72, 73, 74, 96).

d) Topographic distribution of the mammary vascular abnormalities. The variable spatial extent presented by the elementary abnormalities of the vascular tree is a very important element for the CT. interpretation; for this reason it should be independently considered. It is necessary, at first, to look for the concomitant

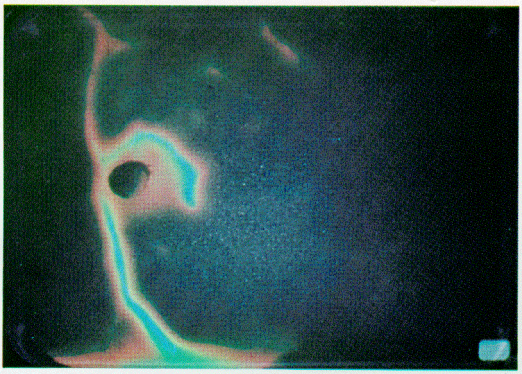


Fig. 71. *Carcinoma located behind the areola*; left breast; lateral view. *Vascularization*: an enlarged vessel arising from the lower-medial quadrant presents a straight course towards the areola, surrounding it; the vessel's terminal part has a «club-like» pattern; a main branch of the medial peduncle reaches the abnormal vessel; lack of the other vascular components (due to the blood deviation towards the tumoural arterio-venous fistula). *Nipple*: hypothermic, with sharp borders. *Background*: large «hot spot» in the areolar region.

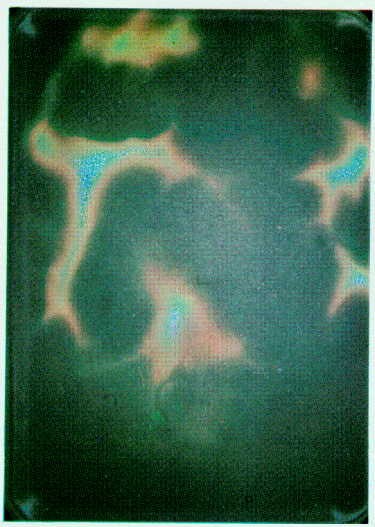


Fig. 72. *Fibrocystic disease*; left breast; frontal view. *Vascularization*: the slightly enlarged main branches of the lateral and medial peduncles present their terminal parts with «spicule», «crescent-like», and «sickle-like» pattern. Some multiple impressions (cysts) are also visible. *Nipple*: hypothermic, with sharp borders. *Background*: homogeneously hypothermic.

presence of vascular abnormalities («tumoural star»; peri-tumoural «vascular ring»: III, A, 3, b, γ, i, ii) and/or of associated abnormalities of the nipple (III, B, 2, a, β) and of the background (III, C, 2, a, γ). The presence of these findings is consistent with a malignant lesion. As concerns the extent of the other elementary vascular abnormalities, the following patterns can be described:

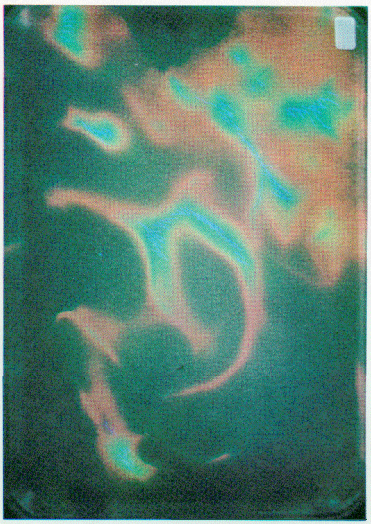


Fig. 73. *Fibrocystic disease*; left breast; lateral view. *Vascularization*: the main branches of the lateral peduncle present a slightly increased diameter and multiple impressions with reduction and bending of the main branch; «crescent-like» pattern of a terminal branch. *Nipple*: not included in the image. *Background*: homogeneously hypothermic.

α) *abnormalities limited to a single peduncle and/or to its main branches*: this pattern is usually related to a benign lesion (vascular traction: healed scar - Fig. 36; vascular compression: solitary mass - Fig. 39); «beaded-like» pattern (Fig. 60), «cork-screw-like» pattern (Fig. 41), «spicule» (Figs. 45, 64), «ladder-like» pattern (Fig. 66), «club-like» pattern (Fig. 70), «sickle-like» pattern (Figs. 66, 96), «crescent-like» pattern (Figs. 46, 64, 73): localized mastosis;

β) *abnormalities limited to the peri-areolar ring*: the involvement of this vascular area (even without other associated abnormalities) should be carefully considered as it does not present valuable differential characters. Usually it reveals intra-canalicular lesions,[34, 69, 84, 85] either inflammatory (galactophoritis: Fig. 90) or tumoural (cancer: Fig. 71). In both situations, a nipple hyperthermia is associated (III, B, 2, a, β, i, ii) and/or an eventual «hot spot» (III, C, 2, b, α) and becomes necessary to perform a mammographic and/or galactographic (when secretion is present) examination for a differential diagnosis;

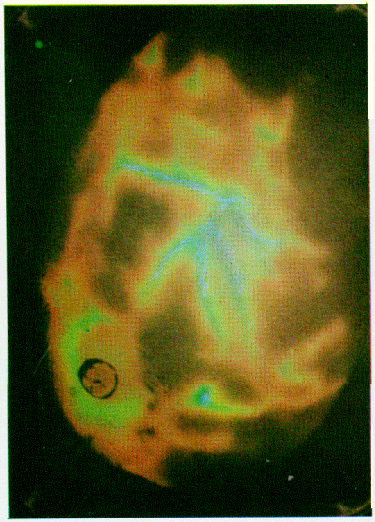


fig 74. *Localized mastosis* of the upper-lateral quadrant; left braast; lateral view. *Vascularization*: the main branches of the lateral peduncle are markedly enlarged; the secondary branches are enlarged and thin, with «spicule» «crescent-like» and «sickle-like» pattern. *Nipple*: hypothermic, with sharp borders. *Background*: homogeneously hypothermic.

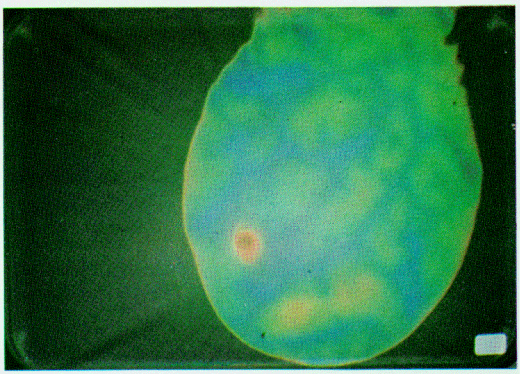


Fig. 75. *Diffuse mastosis*; right breast; frontal view. *Vascularization*: the vascular tree is diffusely enlarged, with wide anastomoses; the secondary branches present «spicule» pattern. *Nipple*: hypothermic, with sharp borders. *Background*: moderate and uniform hyperthermia due to the marked vascular tree.

γ) *abnormalities involving two peduncles and/or their main branches:* the increase of the diameter and the morphological abnormalities of the peduncles, of the main branches (((beaded-like)) pattern: Fig. 61), of the secondary and terminal branches (<<spicule>> pattern - Fig. 75 - and/or <<ladder-like)) pattern - Fig. 65 -) can give some important elements for diagnosing a localized mastosis.

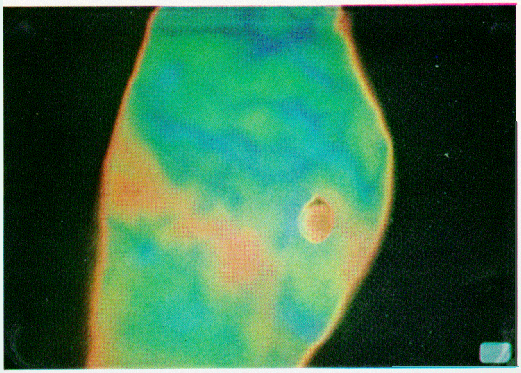


Fig. 76. *Oral contraception*; left breast; frontal view. *Vascularization*: the vascular tree is enlarged and largely anastomosed (3rd grade). *Nipple*: hypothermic, with sharp borders. *Background*: moderate and diffuse hyperthermia in relation to the rich vascularization.

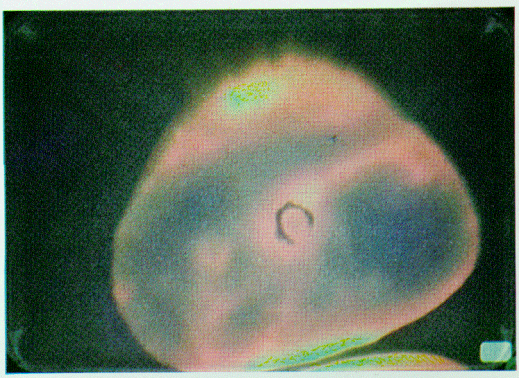


Fig. 77. *Flattening of the nipple* (anatomic variant); right breast; frontal view. *Vascularization*: predominance of the medial peduncle, with main branch directed towards the areola; its terminal part has «ball-like» pattern. Peri-areolar ring slightly represented. *Nipple*: slightly hyperthermic, in relation with the anatomical flattening, with very thin hypothermic border which separates the areolar hyperthermic halo. *Background*: homogeneously hypothermic. The two hyperthermic areas in the upper and lower part of the breast correspond to the infra-mammary sulcus and to the cranial prolongation

δ) *abnormalities extending to the whole mammary vascular tree.* The following situations should be considered: i) *diffuse increase of the vascular diameter*, without abnormalities of the vascular course and morphology and without abnormalities of the breast background and of the nipple: other than para-physiological conditions (III, A, 2, f, γ, δ: pregnancy; lactation – Figs. 34, 78 – contraception – Fig. 76); the hormonal modifications such as hyper-oestrinism (III, A, 3, b, β, i) should be considered;

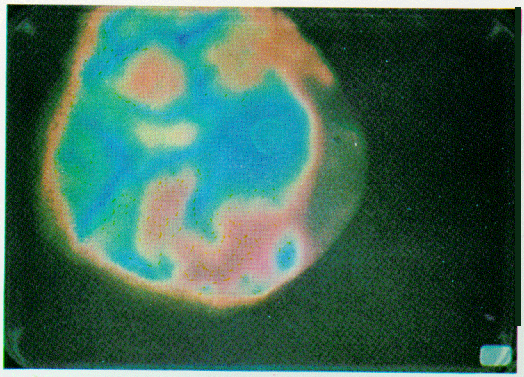


Fig. 78. *Lactation*; right breast; frontal view. *Vascularization*: the vascular tree is markedly enlarged, in particular in the region of the lateral peduncle, with wide anastomoses; marked peri-areolar ring (4th grade). *Nipple*: markedly hyperthermic; visible thin hypothermic border which separates the nipple from the hyperthermic areola. *Background*: areolar hyperthermia.

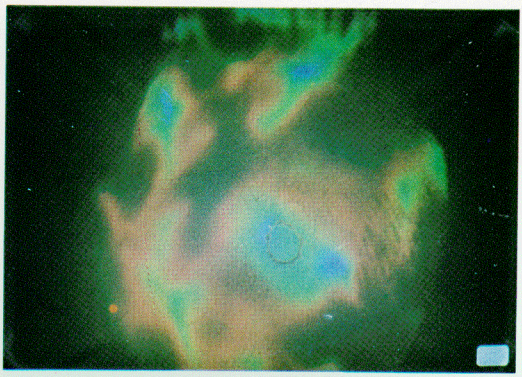


Fig. 79. *Intra-canalicular carcinoma*; left breast; frontal view. *Vascularization*: regular. *Nipple*: markedly hyperthermic with thin border of separation from the hyperthermic areola («target-like» pattern). *Background*: markedly hyperthermic, «hot spot» in areolar region.

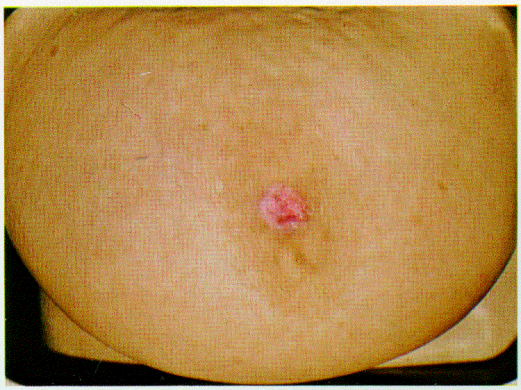
ii) *diffuse increase of the vascular diameter*, without abnormalities of vascular morphology and course, and *with increase of the background temperature* (III, C, 2, a, δ, i): acute inflammatory processes (mastitis: Fig. 47) and recent traumas (Fig. 83 B)[69, 85] can be taken into account; iii) *diffuse increase of the vascular diameter, with abnormalities of the morphology* («beaded-like» pattern: Fig. 61; «spicule» pattern: Fig. 75) sometimes with remarkable hyperthermia of the mammary background and without nipple abnormalities: mastosis;[85, 89] iiii) *diffuse increase of the vascular diameter, with hyperthermic nipple* (III, B, 2, a, β, iiiii) *and background* (III, C, 2, a, γ, i) accompanied by abnormal vascularization («tumoural star», peri-tumoural «vascular ring» (III, A, 3, b, γ, i, ii): carcinomatous mastitis (Figs. 56, 94 B).[23, 69, 84, 85]

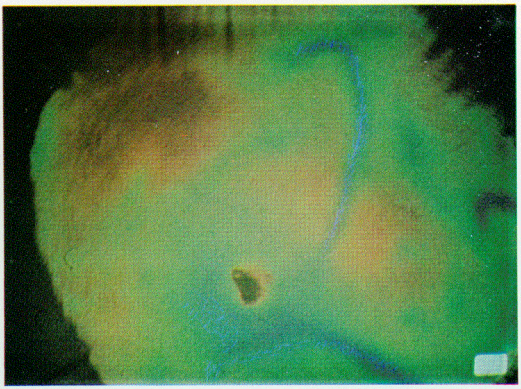
B) NIPPLE

1. C.T. pattern of the normal nipple. The nipple is relatively the coldest region of the breast, when it is erect and has normal structure.[12, 34, 47, 50, 64, 69, 84, 85, 86] With reference to the plates that are usually used (33 and 34), the nipple corresponds to the «blind zone» below the «lower thermal level» (I, C, 2, b), i.d. the infra-red region: for this reason the C.T. image of the nipple is almost always black coloured (Figs. 27, 33, 34 B, 36, 42, 70). Only on the most sensitive plates (31 and 32), the nipple can appear as dark-red (Figs. 26, 29, 32, 65, 69, 74, 75, 76). The nipple, due to its typical hypothermia, presents a C.T. breast pattern that is easily recognizable and is a useful spatial point of reference for localizing the other breast components (normal and abnormal) particularly the vascular ones.[18, 69, 84, 85] The C.T. image of the nipple consists of a round, or oval, black area, perfectly delineated in regard to the breast background,[60, 64, 85] by means of a well defined border (Fig. 74). Except in the 1st grade of the breast vascularization (III, A, 2, f, α), the nipple is usually surrounded by the periareolar venous ring (Figs. 30, 32, 34 A, 65, 69, 77).[85] Nevertheless, the normal nipple can show an hyperthermic pattern when is constitutionally flattened, or even inverted (Fig. 77) («cuvette» effect),[60, 64, 69, 85] or when related to the already mentioned para-physiological situations such as pregnancy (very marked hyperemia of the hypertrophic mammary gland) and lactation[85] (glandular hypertrophy and mechanical irritation caused by sucking: Figs. 34 A, 78).

2. C.T. pattern of the nipple in pathologi-Cal conditions. The analytical elements for evaluating abnormalities of the nipple are represented by the modifications of the thermal level and morphology. It is possible that both elements are associated.

a) Changes of the nipple thermal pattern. Two possible situations are to be considered:





A B

Fig. 80 A-B. *Paget's disease with nipple erosion.* A) *Physical examination*: nipple erosion. B) *C.T. pattern. Vascularization* predominance of the medial peduncle; two main branches with straight course reach the areola (increased flow). *Nipple* hypothermic, with irregular borders (ulceration). *Background*: ill-defined areolar «hot spot».

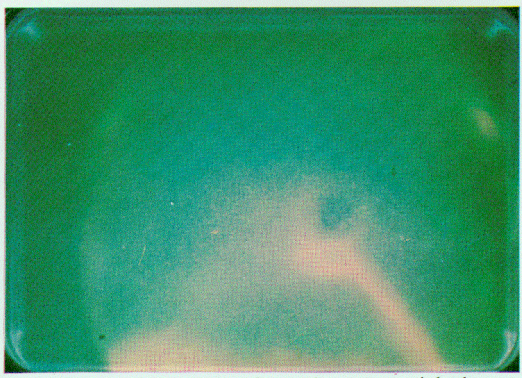
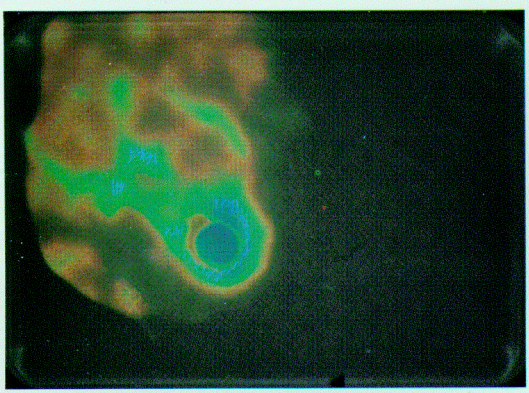
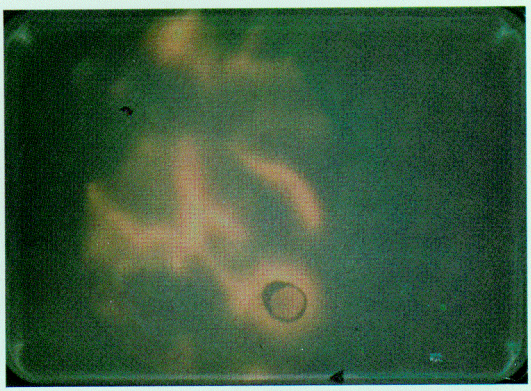


Fig. 81. *Paget's disease with nipple erosion*; right breast; frontal view. *Vascularization*: a branch with abnormal course in the lower-medial quadrant, and with increased diameter (increased blood supply), is tilted towards the nipple. *Nipple*: hypothermic, with ill-defined borders (erosion). *Background*: homogeneously hypothermic, close to the areola there is a «hot spot» reached by the enlarged and tilted branch.

α) *decrease of the nipple thermal level.* There exist some pathological conditions which are hypothetically able to further decrease the nipple T; it is very difficult to demonstrate them by C.T. because of the basal thermal level of the nipple. As already stated, the lower plates (31 and 32) show a C.T. image of the nipple which is dark-red coloured. Only by means of this plates is it possible to identify an abnormal thermal decrease of the nipple. Nevertheless, due to easy recognition by means of inspection of the lesions that cause this C.T. pattern (eczema, ulceration) [85] there is no clinical interest in such a demonstration;

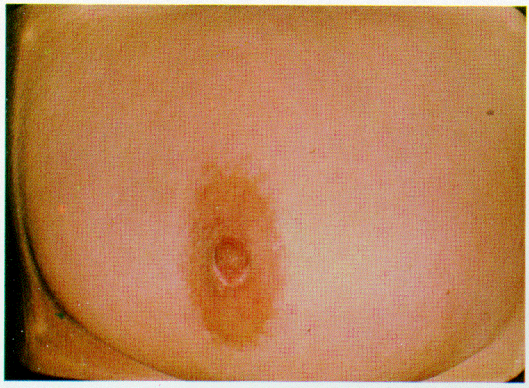
β) *increase of the nipple thermal level.* It is much more important from the clinical point of view than the decrease. Hyperthermia very rarely remains localized in the nipple area: in





A B

Fig. 82 A-B. *Retro-areolar abscess*; left breast; frontal view. A) *Acute phase. Vascularization*: the main branches of the medial peduncle are slightly enlarged and anastomosed in the marked peri-areolar ring. *Nipple*: markedly hyperthermic separated by a thin hypothermic border from the areolar hyperthermia. *Background*: slight «hot spot» near the areola. B) *Control (after antibiotic therapy and spontaneous empty)*: C.T. pattern normalized.



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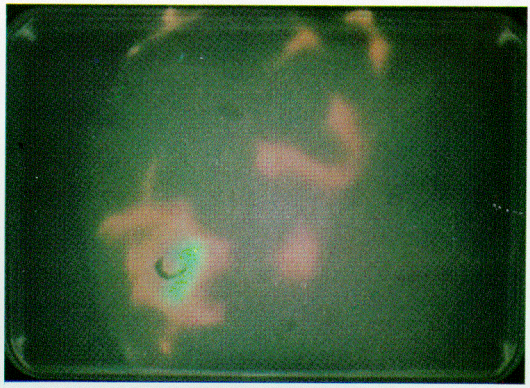


B

Fig. 83 A-B. *Recent traumatic lesion of the nipple: bite*; right breast; frontal view. A) *Physical examination*: abrasion at the base of the nipple. B) *C.T. pattern. Vascularization*: peri-areolar ring moderately represented. *Nipple*: hyperthermic, with thin hypothermic border corresponding to the lesion Background small <<hot spot>> in the areolar region.

most situations it extends to the areola. Sometimes the hyperthermic nipple is separated from the hyperthermic areola by a thin hypothermic ring, which is due to imperfect adhesion of the plate to the skin at the border between the nipple and the areola («target-like» pattern: Figs. 79, 82, 86B, 87, 88B, 91). The lesions which cause nipple hyperthermia can correspond topographically to its site (abnormalities of the nipple, of the areola, and of the structures immediately below them) or can be situated, as well, at quite a distance from the nipple (deeply located tumours). In the latter situation,[34, 64, 69, 84, 85] the heat is almost completely transmitted to the nipple through the lactiferous ducts. There are many breast lesions characterized by the nipple hyperthermia.

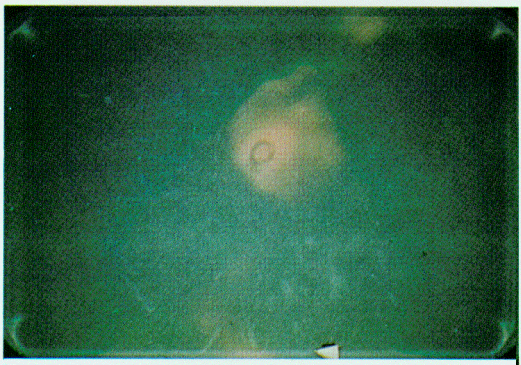


Fig. 84. *Iatrogenic gynecomastia* (prolonged digitalic treatment); left breast; lateral view. *Vascularization*: linear vascular structures are not recognizable. *Nipple*: markedly hyperthermic. *Background*: the peri-areolar ring and the areola are markedly hyperthermic.

i) *Initial Pager's disease; intra-canalicular retro-areolar carcinoma.*[18, 23, 31, 34, 47, 50 52, 64, 69, 85] The nipple is usually hyperthermic in the retro-areolar carcinoma (Figs. 49, 79). On the contrary the nipple hyperthermia is compatible with **PAGET'S** disease until it has not reached the nipple, with the typical chronic ulceration. In this situation (Fig. 80B) the nipple hypothermia increases with changes of the nipple morphology (III, B, 2, b, a). The association of other abnormalities, particularly those of vascularization, should be carefully evaluated for the differential diagnosis. A localized dilatation of contiguous vessels, with abnormal course («tumoural star» or «vascular ring» patterns: 111, A, 3, b, y, i, ii), gives a sure indication of malignant lesion (Fig. 81).

ii) *Inflammatory* (retro-areolar abscess: Fig. 82) or *traumatic* (Fig. 83) *lesions.*[60, 69, 85] The thermal change of the nipple in these lesions should be carefully evaluated together with the modification of the other breast components: in particular, the inflammatory processes - especially when they are diffuse - present a marked increase of blood supply,[84, 85] with widespread dilatation of the main branches (Fig. 82A) and with an increased number of the secondary branches (III, A, 3, b, β, ii). Nevertheless the harmony of the blood supply is preserved, unlike that which occurs in the tumoural forms. The hyperthermia of the nipple, when caused by inflammatory lesions, rapidly regresses under medical or surgical treatment (Fig. 82B).

iii) *Gynecomastia:* when the male mammary

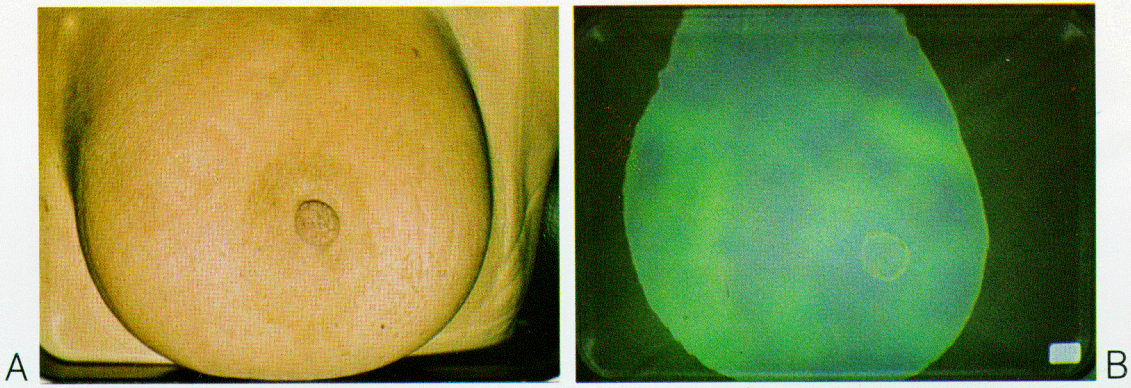


Fig. 85 A-B. *Carcinoma treated by radiation therapy*: follow-up after two months; left breast; frontal view. A) *Physical examination:* scleredema due to the radiation therapy. B) *C.T. pattern. Vascularization*: the vascular tree is not recognizable because of the diffuse oedema. The vessels are fragmented in hyperthermic spots with ill-defined borders. *Nipple*: markedly hyperthermic, with sharp borders. *Background*: markedly diffuse, not homogeneous hyperthermia («thermal tide»).

gland presents an abnormal development, the nipple is usually slightly or even markedly hyperthermrc (Fig. 84). This pattern permits to differentiate the gynecomastia from the pseudo-gynecomastia: the latter, in fact, is characterized by an increase of the retro-mammary fat tissue and does not cause thermal changes of the nipple.

iiii) *Conservative radiation therapy of breast cancer.* The «thermal tide» [26, 27, 39, 68, 79, 84, 85] can be observed during and immediately after radiation therapy. The phenomenon is characterized by an intense accentuation of the vascularization, an increase of the background and nipple T (Fig. 85). The «thermal tide» disappears within six months. The persistence of the nipple hyperthermia is consistent with an incomplete tumour sterilization, while the reappearance of the hyperthermia, after an initial regression,[47, 68, 84, 85] can be caused by a recurrence (Fig. 86).

iiiii) *Deeply located tumours.* In this situation, the nipple hyperthermia is caused by the preferential transmission of heat through the lactiferous ducts. The tumour may also show

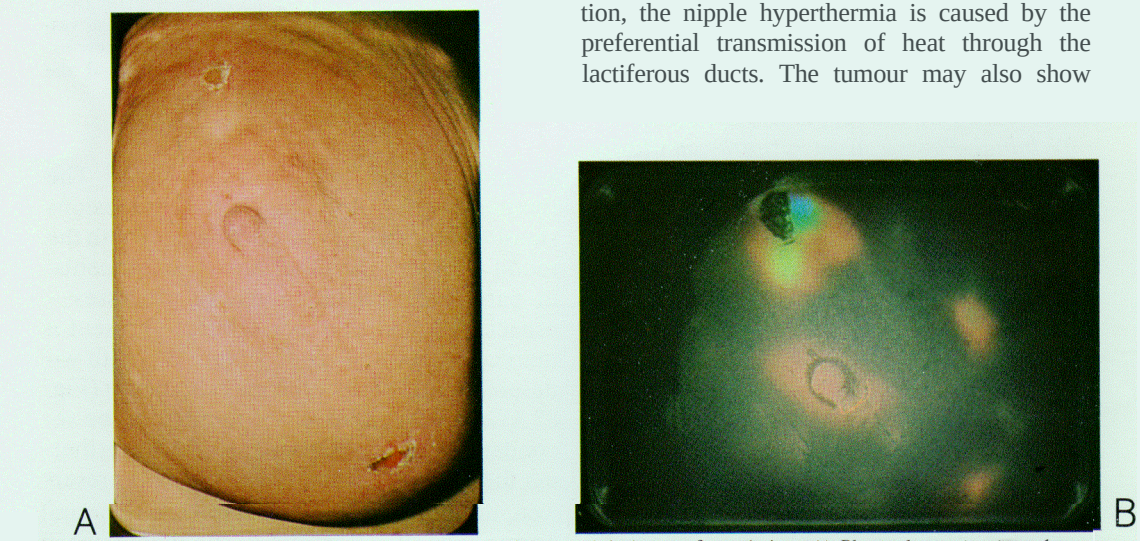


Fig. 86 A-B. *Neoplastic recurrence* following radiation therapy; right breast; frontal view. A) *Physical examination:* ulceration due to a recurrence in the upper-lateral quadrant of the breast; another ulceration caused by radiodermatitis is visualized in the lower-medial quadrant. Skin sclerosis following radiation therapy. Masses are not palpable behind the areola. B) *C.T. pattern. Vascularization*: the vascular tree is not recognizable (due to the skin sclerosis). *Nipple*: markedly hyperthermic with a thin hypothermic ring between the nipple and the areola («target-like» pattern) due to the lack of adhesion between the plate and the skin. *Background*: hypothermic area corresponding to the ulceration, surrounded by an intense and ill-defined «hot spot» (recurrence).

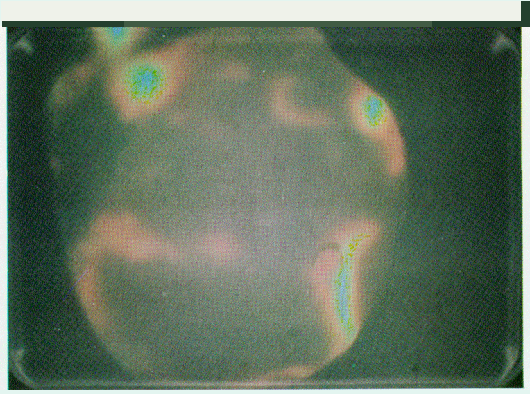


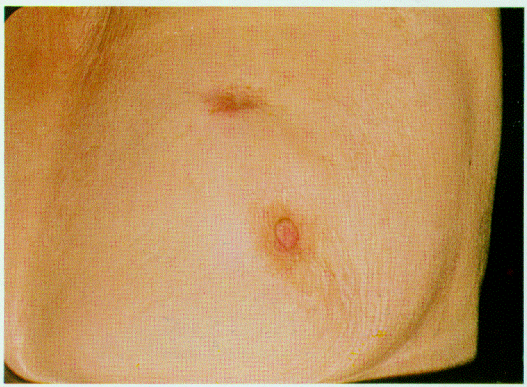
Fig. 87. *Carcinoma* in the upper-medial quadrant; left breast; frontal view. *Vascularization*: the vascular tree is ill-defined and fragmented (oedema). *Nipple*: hyperthermic, with sharp borders. *Background*: homogeneously hypothermic

other typical C.T. patterns (changes of the background T: «hot spot»: III, C, 2, b, α; changes of the vascularization: abnormal course: III, A, 3, b, γ, i, ii) that in such cases are added to the nipple hyperthermia. This case represents a typical C.T. pattern (Figs. 52, 56). Nevertheless, it is also possible that, in particular situations, the «hot spot» is not recognizable (Figs. 87, 91: deeply located tumour and/or slight spontaneous heat emission and/or shielding effect from oedema: III, C, 2, a, γ, i). In other cases neither the «hot spot» nor the vascular changes (presence of peri-focal oedema: III, C, 2, c, η) are recognizable. In these lesions (Figs. 86B, 88B) the nipple hyperthermia can be the only C.T. sign.[23, 69, 85] In any case, when nipple hyperthermia is seen in malignant lesions located at some distance from the nipple, this finding usually indicates an aggressive cancer.[64, 69, 84, 85]

b) Changes of the nipple morphology. The C.T. image of the nipple can be modified – even if the thermal level does not change – because of border alteration and size modifications. The following patterns can be visualized:

α) *nipple dimensionally unchanged*, but with *ill-defined borders*: this is characteristic of PAGET's disease, in the ulcerating phase,[69, 85] where the nipple borders appear ill-defined (Figs. 80, 81). In this case, the other C.T. findings in initial PAGET's disease (III, B, 2, a, β, i) persist, i.d. the abnormal hyperthermia of the areola and the signs of contiguous abnormal vascularization. Eczema of the nipple can also show such a C.T. pattern; nevertheless the collateral findings already described in PAGET's disease are usually missing, except when the eczema is associated with a marked inflammatory component;

β) *nipple of increase size and with ill-defined borders*: this findings occurs in retraction, no matter the cause (Fig. 63). This situation avoids the complete adhesion of the plate to the nipple and to the adjacent areolar plane which is partially depressed.[69, 85] The evaluation of the associated abnormalities of the other component of the C.T. pattern (vascularization and background) can be used to differentiate the constitutional nipple retraction from the retraction secondary to cancers and chronic inflammatory processes of the breast (plasmacell mastitis).



A B

Fig. 88 A-B. *Carcinoma with ulceration* of the upper-medial quadrant; left breast; frontal view. A) *Physical examination*: peri-areolar skin and nipple retraction. Skin ulceration. B) *C.T. pattern. Vascularization*: the vascular tree is not visible because of the oedema. *Nipple*: markedly hyperthermic, with a hypothermic border. *Background*: irregular «hot spot» corresponding to the tumour, with central hypothermic area (ulceration).

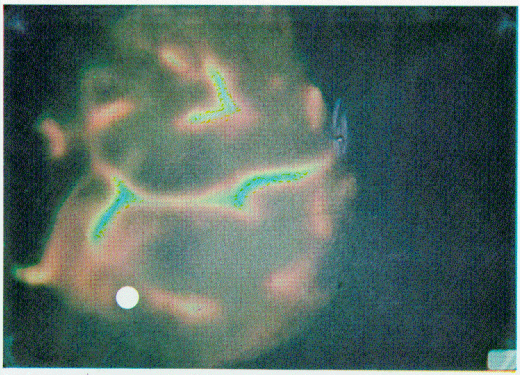


Fig. 89. *Normal case*; left breast; lateral view. *Vascularization*: the superior communicating vessel is well represented. *Nipple*: not visible (marker point). *Background*: homogeneously hypothermic.

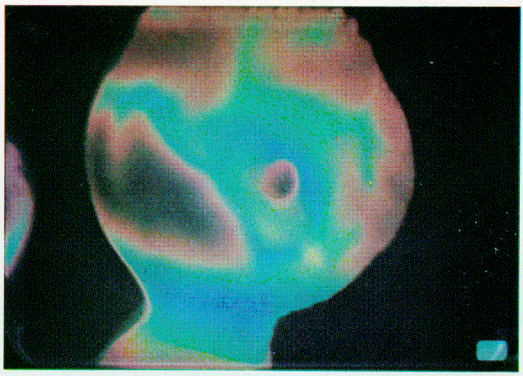


Fig. 90. *Galactophoritis*; left breast; frontal view. *Vascularization*: the peri-areolar ring and the vessels having radiate course towards the nipple present a marked enlargement. *Nipple*: hypothermic, with sharp borders. *Background*: marked areolar «hot spot».

C) BACKGROUND

1. C.T. pattern of the normal breast

) In women of fertile age, with medium developed breasts, the background T is homogeneously distributed and is constantly lower than the vascular tree T.[12, 22, 23, 34, 41, 84, 85] For this reason the C.T. pattern of the background is placed at the <<lower thermal level)) (I, C, 2, b) appearing red or dark-red coloured on the CT. plate (Fig. 89). In this way, the temperature difference necessary for representing the vascular tree is maintained (II, B, 1, b). The vascular tree presents T values corresponding to the medium region of the plate <<Syntonization band>> (green colour: 11, B, 1, a). The background T depends on the anatomical development of the mammary gland, on its metabolic activity, and on the fat contained in the supporting tissue.[29, 32, 33, 65, 84, 85] Therefore, a breast with underdeveloped glands is relatively hypothermic (Fig. 33); analogously, the background T is rather low - because of the poor thermal conductivity of the fat tissue - in breasts whose glands, normally developed, are separated by a large fat layer (Fig. 42). The background T is also influenced by the grade of vascularization;[62, 84, 85] it has been already demonstrated that in the 3rd and 4th grade (III, A, 2, f, γ, δ), the marked increase of the vascular tree influences the background T too, (Fig. 34A) requiring the serial use of the plates (33 or 34). Nevertheless, some temperature difference between the background and the vascular tree remains still visible in this situation too, adopting the ((preliminary cooling)) (II, B, 1, e, a): Fig. 34B.

b) During infancv and pre-puberty years, because of the&or of initial growth of the mammary glands, the background T is similar to the contiguous skin areas T. This is due to the rather thin thoracic wall which permits the heat of the deep bone and muscles layers to be transmitted to the skin. The male breast usually has this pattern.

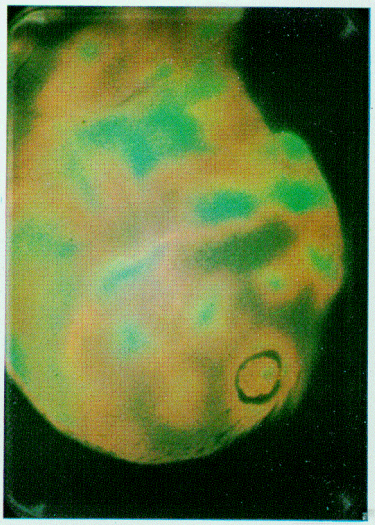


Fig. 91. *Scleredema following radiation therapy*; left breast; frontal view. *Vascularization*: the main branches are squat and fragmented. *Nipple*: hyperthermic, with thin border of separation from the hyperthermic areola. *Background*: widespread hyperthermia.

C) During the menopause, the involution of mammary glands increases the background hypothermia [23, 41, 65, 85] as the proportion of fat in the breast increases (Fig. 42).

2. CT. pattern of the pathological breast. The modifications of the background T can occur according to two different C.T. patterns (hypothermia or hyperthermia). It should be said that it is difficult to assign some clinical meaning to C.T. patterns characterized by a decreased background T. In fact, this appearance can be found in perfectly normal breast (as described above). On the other hand, the pathological decrease of the background T - particularly when diffuse - is not usually associated with modifications of the other C.T. pattern components (vascular tree and nipple): therefore, a diffuse cool breast is seen, where the differential diagnosis is difficult. On the contrary, it is easier to decide the clinical meaning of a C.T. pattern where the background T is increased, due to its association with other modifications of the breast components.

a) Increase of the background temperature. The increase in the background T can be due to several causes.

α) *Increased metabolism* of the mammary gland [22, 23, 25, 33, 41, 44, 65, 85, 90] wether due to a physiological or para-physiological causes (contraception: Fig. 76; premenstrual phase: pregnancy; lactation: Fig. 34A), or due to primary or secondary hormonal changes (gynecomastia: Fig. 84): in these situations, the increased background T is diffuse all over the breast and is bilateral; the vascular tree is more evident but unchanged in its course; the nipple is regularly hypothermic.

β) *Inflammatory process*, wherever located (skin, supporting tissues, duct, gland): in these situations, the extent of the increased background T depends on inflammatory process diffusion [23, 69, 85, 88] Therefore the galactophoritis (Fig. 90) is characterized by a localized <<hot spot» (III, C, 2, b, α, β), while the mastitis (Fig. 47) shows a diffusely increased background T (III, C, 2, b, y, 6). In these situations the vascular tree (Fig. 47) can be markedly increased without changes in its course and morphology (III, A, 3, b, β), except for diffuse long standing inflammatory processes. The nipple, on the contrary, can be hyperthermic, either when the inflammatory lesion, cutaneous or subcutaneous, corresponds to its site (Fig. 82A) or when the inflammatory lesion is severe and diffuse (mastitis). It is evident that, in the latter situation, the differential diagnosis with carcinomatous mastitis is very difficult, both CT. patterns being similar (Fig. 56). A very particular inflammatory process, where the cause is a physical rather than an infectious source, is the radiation therapy of the breast cancer [23, 26, 27, 39, 47, 68, 79, 84, 85] In this case, the background T increases markedly with a notable increase of the vascular tree, the modifications lasting for about 6 months after the treatment end (<<thermal tide)): Fig. 85B). Later on. the background T decreases markedly, without reaching the normal values in most of the cases (Fig. 91). When the background T does not decrease after the ((thermal tide>> or when a new hyperthermic rush appears (Fig. 86), it is necessary to suspect that an incomplete sterilization of the tumour has been achieved or a recurrence has developed.

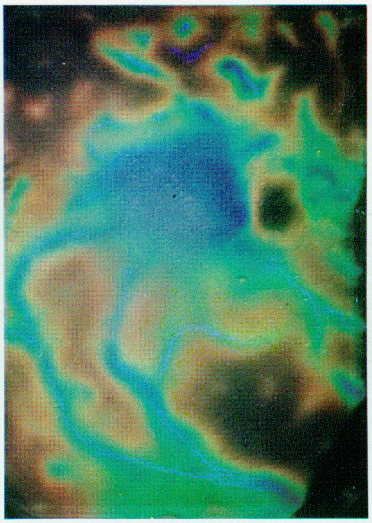


Fig. 92. *Carcinoma* of the upper-lateral quadrant; right breast; lateral view. *Vascularization*: the marked enlarged vessels with abnormal course converge to form a «tumoural star» corresponding to the tumour. *Nipple*: not included in the image. *Background*: marked hyperthermic area («hot spot») at the convergence point of the abnormal vessels.

y) Neoplastic lesion. The tumour produces autonomously some heat, because of the abnormal metabolism of the carbon-hydrates in

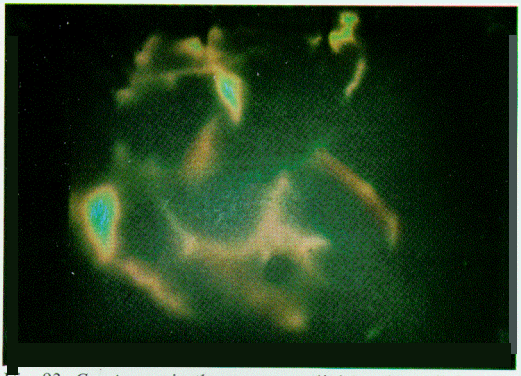


Fig. 93. *Carcinoma* in the upper-medial quadrant (1.5 cm in [illegible] of the main branch of the medial peduncle corresponding to the tumoural mass. *N'ipple:* hypothermic, with sharp borders. Backgromd: homogeneously hypothermic.

the neoplastic cell: therefore, in the highly vascularized cancers (arterio-venous neoplastic fistula: III, A, 3, b, y) the hyperthermia of the neoplastic mass is self-produced and does not depend on the increased arterial blood supply. In fact, the T of the arterial blood supply is lower than the T of the neoplastic mass.-* [3, 13, 23, 24, 28, 33, 51, 65, 67, 71, 78]

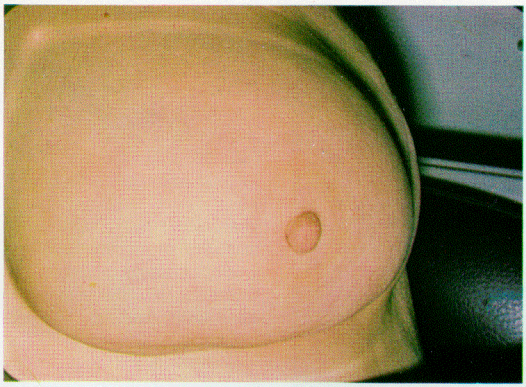
i) The *mono-jbcal cancer,* as an autonomous heat producer, can appear on the skin surface as a hyperthermic area (<<hot spot>>), as the consequence of the heat transmittance through the tissues (conductivity) and through the blood vessels (convection). Considering a given heat emission from a cancer, a trhot spot>> (Fig. 92) is easier to find by C.T. how superficial the lesion is and how raised the thermal transmittance is through the interposed tissues.[22,23,26,65,71] The size of the neoplastic mass influences the C.T. pattern of the trhot spot>> (except for the large masses which are often hypothermic because of their extensive necrosis). Although the growth rate of the neoplastic cells progressively decreases with the increase of the cancer size (the related heat is less intense), in absolute terms, the heat production of the cancer increases with the size of the neoplastic mass. Therefore, the low heat production of very small cancers can be absorbed by the interposed tissues and thus does not appear on the skin surface (Fig. 93).

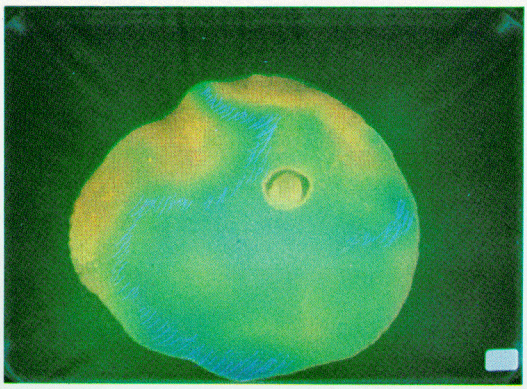
ii) *Multi-focal cancer or diffuse cancer.* The multi-focal or diffuse cancers are not usually characterized by a C.T. <<hot spot>>: on the contrary, they present a generalized and sometimes not homogeneous increase of the background T. On the contrary, carcinomatous mastitis (diffuse tumour with associated an inflammatory process) presents a C.T. typical pattern, when interpreted according to case history and clinical data (absence of trauma or of causes determining infectious processes). In this lesion the background T is markedly increased (as far as 5°C), with not homogeneous appearance and involving the whole or a large part of the breast (Figs. 56, 94B).

Either in mono-focal cancers or in multi-focal and diffuse cancers, the evaluation of breast background hyperthermia should take into account the pattern of the other breast components (vascularization and nipple) which facilitate the correct interpretation of the increased background T.

b) C.T. pattern of the increased background temperature. Two findings should be carefully considered: the extent of the hyperthermic area and the AT characterizing it; AT is the thermal difference between the hyperthermic area and the surrounding structures (in localized hyperthermia) or between the hyperthermic breast (when hyperthermia is extended to the whole breast) and the contra-lateral breast (the latter comparison is possible when examining simultaneously both mammae by the same plate: II, B, l, f, δ). These two parameters, on the other hand, cannot demonstrate the lesion site (superficial, half-deep, deep). The most useful of the two findings, from the practical point of view, is AT, because it permits the recognition of the C.T. pattern of the lesion. The following features can be considered:

a) localized increase of the background temperature (hot spot) with ΔT *higher than* $2^{\circ}C$. This feature can be found[2,3,19,23,24,26,28,34,39,42,45,65,67,69,80,85] in: i) *high heat producing cancers* (either primary cancers: Fig. 92, or metastases). The deeper the cancer is, the more intense has to be the autogenous heat production; in these cases there could not be a well localized and homogeneous trhot spot>> (Fig. 95); ii) *skin recurrences* after radiation therapy (Fig. 86B); iii) *inflammatory lesion,* either superficial (galactophoritis: Fig. 90) or deep in the mid-breast (abs-





A B

Fig. 94 A-B. *Carcinomatous mastitis*; left breast; frontal view. A) *Physical examination*: oedematous breast with «peau d'orange» appearance. B) *C.T. pattern. Vascularization*: the vascular tree is not recognizable because of the diffuse oedema *Nipple*: slightly hyperthermic. *Background:* markedly, diffusely and not homogeneously hyperthermic.

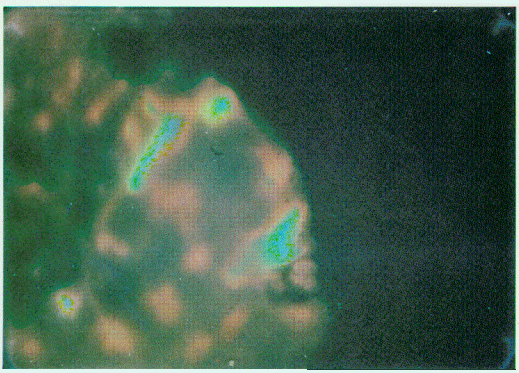


Fig. 95. *Carcinoma deeply located* of the lower-lateral quadrant; right breast; lateral view. *Vascularization*: the main branches are squat and fragmented. *Nipple*: moderately hyperthermic. *Background*: marked hyperthermia in small mottles.

cess, suppurated cyst: Fig. 82A); iiii) *recent trauma* (hematoma: Fig. 83B);

p) localized increase of the background temperature (hot spot) with AT *lower than 2°C.* It can be due to C.T. artifacts only (convergence or crossing of vessels). The ((dynamic test)) with cooling (II, B, 1, e, β) can easily demonstrate it (Fig. 96). When the C.T. <<hot spot>> is confirmed, the possible causes are the same as previously described; the abnormalities which cause an extensive and intense increase of the background T should be also taken into account (III, C, 2, b, δ);

γ) *extensive increase of the background temperature with* AT *higher than* 2°C. This feature could be found [2, 3, 19, 22, 23, 24, 34, 65, 67, 69, 80, 85] in: i) diffuse cancer with a high growth rate *(carcinomatous mastitis*, Fig. 56, 94B); ii) acute and diffuse inflammatory process *(mastitis:* Fig. 47); iii) *thermal tide* after radiation therapy (Fig. 85B);

6) extensive increase of the background temperature with AT *lower than* 2°C. The partial breast involvement (2 quadrants) is more usual [23, 27, 42, 85] than the total one, as just mentioned. Such a pattern can be found in: i) *chronic inflammatory process* (plasmacell mastitis: Fig. 61); ii) *fibrocystic disease* with associated inflammatory lesions (Fig. 69); iii) previous *trauma* (healing hematoma); iiii) *sequelae of the radiation therapy,* after the disappearance of the <<thermal tide>> (Fig. 91).

c) Decrease of the background temperature. As the basal thermal condition of the breast background is hypothermia, the decreased background T has to be remarkable in order to be detected during C.T. examination. The decreased background T could be caused by:

a) mastectomy: " the skin surface appears homogeneously hypothermic;

β) *protruding skin lesions* [23, 60, 85] without loss of tissue (warts, naevi, angiomas, scars). The hypothermic area is well defined and corresponds exactly to the anatomical extent of the lesion (Fig. 97);

γ) *skin ulcers*: [50, 69, 85] the hypothermic area corresponds exactly to the extent of the lesion, but its boundaries are not well defined (Figs. 80B, 81, 83B, 86B, 88B);

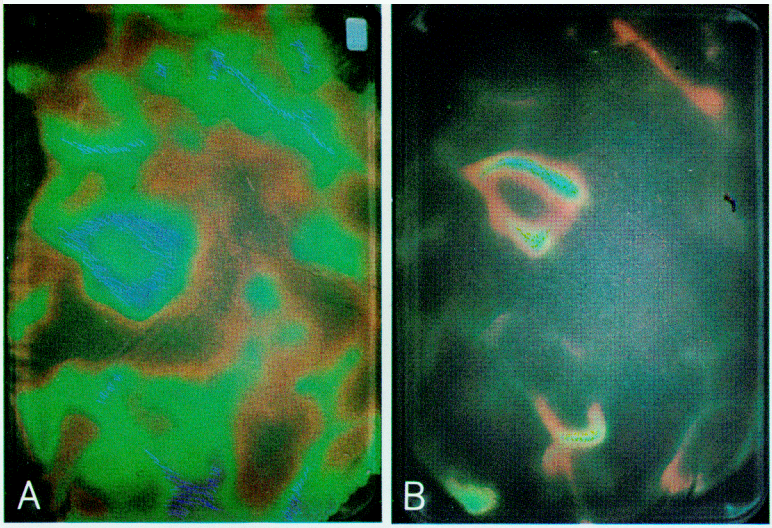


Fig. 96 A-B. *Diffuse mastosis*; left breast; lateral view. A) *Basal conditions. Vascularization*: the vascular tree is slightly and diffusely enlarged; the main branch of the middle peduncle simulates a «hot spot» with complete «vascular ring». *Nipple*: not included in the image. *Background*: homogeneously hypothermic. B) *After «dynamic test»* with cooling. The elimination of the lowest T values permits the best definition of the middle peduncle, whose terminal branches present «club-like» and «sickle-like» pattern, which mimic peri-tumoural «vascular ring».

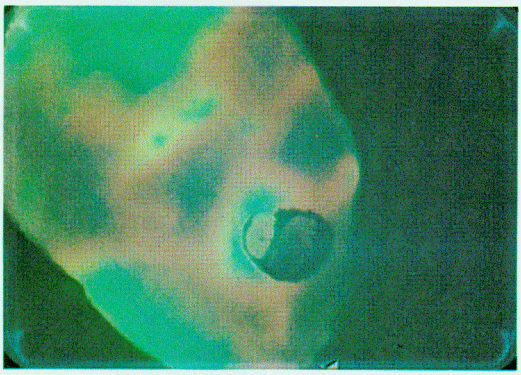


Fig. 97. *Large wart* in the lower-medial edge of the nipple; right breast; lateral view. *Vascularization*: regular. *Nipple*: hypothermic, placed laterally to the wart. *Background*: markedly hypothermic area, with regular borders, corresponding to the wart; it is well defined by a thin hypothermic halo due to the incomplete adhesion between the plate and the skin.

δ) *skin retraction*,[52, 69, 85] either localized (benign forms as surgical scars or Seato-necrosis, and malignant forms as a mid-breast skin infiltrating cancer: Fig. 88), or extensive (<<peau d'orangc skin>>: Fig. 98): in these cases the hypothermia depends on the lack ofadhesion between the plate and the retracted skin. The C.T. pattern exactly reproduces the retraction area while the hypothermic area boundaries are ill-defines;

ε) *benign masses, located in the mid-breast*[23, 85, 86, 88] well defined (cysts, lipomas, adenomas, incapsulated old hematomas): the hypothermic area corresponds to the lesions anatomical extent, its boundaries being ill-defined (Figs. 39B, 40, 72, 73): in these cases, the signs of impression and displacement on the vascular branches should be evaluated (III, A, 3, a, β);

ζ) *breast prosthesis*:[85] the foreign matter (silicone) acts as a shield preventing the diffusion of heat and compresses the superposed breast tissues, causing their relative hypo-vascularity: the breast appears remarkably and extensively hypothermic, with minimal vascularity (Fig. 99);

η) *oedema*[52, 69, 84, 85] of the gland and/or of its supporting tissues: this finding is usually found in cancers with high growth rate: in these cases the heat emissivity from the cancer, particularly when deeply located, can be completely absorbed by the oedema (Figs. 54, 55, 87, 93). Consequently, the signs for the interpretation are based on the vessels and nipple pattern. Nevertheless, when the oedema is remarkable, the vascular pattern can be completely masked or greatly modified (Figs. 94B, 98): the disagreement between clinical and thermographic data should be taken into consideration, in this case;

ϑ) *diffuse fibrosis* substituting the glandular tissue: it can be found in the fibrocystic disease with remarkable fibrosis and without superimposed inflammation: in this case the typical vascular changes of the mastosis (III, A, 3, b, c) are easily recognizable due to the remarkable background hypothermia (Fig. 45), unless a

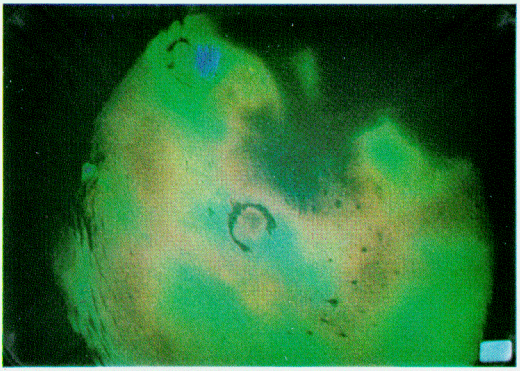


Fig. 98. *Carcinoma with «peau d'orange» pattern*; right breast; frontal view. *Vascularization*: the vascular tree has an increased and ill-defined diameter due to oedema. *Nipple*: slightly hyperthermic. *Background*: diffuse and dishomogeneous hyperthermia, with several minute hypothermic dots («mottled» pattern) related to the skin retraction («peau d'orange»).

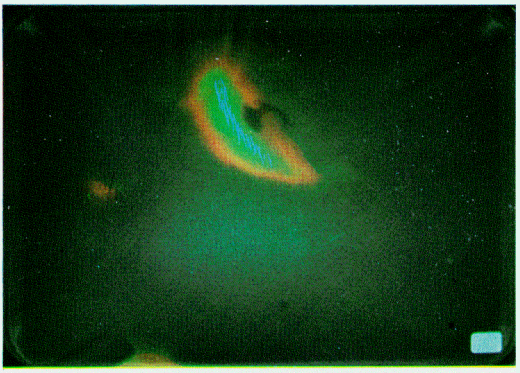


Fig. 99. *Breast prosthesis (silicon)*; left breast; frontal view. *Vascularization*: only the peri-areolar ring is visible. *Nipple*: hypothermic, with sharp borders. *Background*: homogeneously and markedly hypothermic.

contemporary decrease of the vascular tree prevent the detection of the morphological pattern;

L) mammary gland functional modifications depending on *endocrine diseases.* The typical example is the prolactin producing pituitary adenoma (amenorrhea and galactorrhea). The persistent decrease of the oestrogens and progesterone levels (Fig. 43) stops the cyclic changes in the gland, reducing the breast vascularization (III, A, 3, b, a, i): as a consequence, there is a remarkable and extensive hypothermia of the breast background with marked reduction of the vasculartree:'breasttotallycool(Fig.44).

d) C.T. pattern of the decreased background temperature. According to this poorly significant finding, the hypothermia extent only should be considered:

a) localized hypothermia: this finding could depend on the skin lesions (easily detected during inspection) or on half-deep lesions. When vessel impressions are found (III, A, 3, a, p), without changes of the vascular morphology, the benign nature of the lesions should be taken into account (Fig. 72);

β) *diffuse hypothermia*: the differential diagnosis is difficult, if based only on the C.T. patter: very different anatomo-pathological abnormalities can present the same C.T. pattern (fibrocystic disease with remarkable fibrosis: Fig. 45; extensive peri-tumoural oedema: Fig. 87; endocrine disease: Fig. 44; application of mammary prosthesis: Fig. 99). The Senologist should take into account the clinical details other than the associated abnormalities of the vascularization, of the nipple, etc. Only by this evaluation he can obtain, from CT. technique, the maximum information and the greatest value.

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