3. CONTACT THERMOGRAPHY IN BREAST CANCER

Introduction to the theme

by G.C. MALTONI
Centre of Preventive Medicine, Florence (Italy)

Mass screening of early breast cancer requires the application of a diagnostic test to large numbers of women or to entire female communities. Moreover, the screening test should be able to detect small lesions in asymptomatic women and in the pre-clinical phase; in the same time the screening test should be relatively unexpensive, require a minimum of time in performance and be free of discomfort.

1. Mammography (M.) is well known as the best diagnostic test in mass screening for its good sensibility and specificity especially in early lesions, but it is quite expensive, potentially hazardous and can be thus utilized as a screening test only in women over 40 yrs of age.

2. For these reasons, **infra-red thermography** (I.T.) met great interest in the early diagnosis of breast cancer as a new and different method based on biological more than morphological signs; it was included in some screening programs - as the Breast Cancer Detection Demonstration Project - as a potential substitute for M. in the first routine phase.

These experiences did not assess the effectiveness of I.T. in the early diagnosis of breast cancer, because of its low sensibility and specificity, and M. was confirmed as the best currently available modality for the detection of breast cancer, particularly the minimal lesions.

3. Contact thermography (C.T.) more recently introduced, allows to reach almost the same results of I.T. as to sensibility and specificity, although the information it provides is different and more specifically based on the breast's vascular patterns. Nevertheless, some features of the C.T. examination, such as low cost of the unit and of its management, absence of any hazardand the information provided, different from the other diagnostic methods - are attractive.

4. The opportunity of studying the efficacy of the **association** of C.T. examination to physical (P.E.) and M. examinations, is suggested: this, particularly in young women (under 40 yrs of age) and even in older women with dysplasic dense breasts which are not completely clear at P.E. and M. examinations.

5. Finally, it must be remembered that the **limits** of the C.T. examination, particularly its low sensibility and specificity, do not consent to extend it routinely to all women. Consequently, the C.T. examination could be included in controlled screening programs in order to assess its best role in early breast cancer detection.

Contact thermography in the diagnosis of breast cancer

by G LUZZATTI and L DELLAFIORE

Department of Radiology, <<San Carlo Borromeo- Hospital, Milan (Italy)

Summary. A total of 198 breast cancers have been diagnosed in symptomatic women. The results achieved by Physical Examination (P.E.), Xerornammography (X.M.) and Contact Themlography (CT.) are described The necessary use of X.M. In symptomatic women is emphasized, whereas the diagnostic gain provided by CT. in association with X.M. (15.5%) is stressed too. The Authors do also draw the attention to the important diagnostic gain achieved by C.T. in association with P.E. (9.5%); this makes the combined use of P.E. and C.T. useful in the clinical appreach to asymptomatic women.

Key WOrdS: xeromammography, contact thermography, breast cancer, physical examination, combined diagnostic methods.

A) INTRODUCTION

Aim of this paper IS to establish the role 01 contact thermography (C.T.) in the diagnosis of breast cancer in symptomatic women and the best continuous use of C.T. with the other diagnostic methods, such as physical examinatlon (P.E.) and xero-mammography (X.M.).

The present series consists of 198 breast cancers, of which 158/198 were histologically, 4/198 citologically and 36/198 clinically confirmed.

B) METHOD

The present series of breast cancers was studied as follows:

1. The physical examination was always the first method utilised, being both C.T. and X.M. correctly adresscd by it.

2. The xero-mammography follows **as** a rule the P.E. examinatlon.

(1) When no breast mass is identified at P.E. (i.e. breast dysplasia), X.M. is required in order to identiry a possible occult cancer not detectable at P.E. for the following reasons: a) diffuse type of breast cancer: the X.M. could demonstrate micro-calcifications spread (Fig. I); β) *small size* of nodular breast cancer, less than 5 mm in diameter (Fig. 2); γ) *hiding* of the tumoural nodule in some fibrotic magma (i.e. fibrocystic disease [Fig. 3]); δ) *difficult clinical approach* to some particular site (i.e. close to the chest wall in very large breasts).

b) When some problems of *differential diagnosis* arise at P.E. that is, for example, in PAGET's disease, in which it is necessary to identify a possible nodule under the skin lesion, because in this last evenience the surgical treatment ought to be more radical (Fig. 4).

c) When a malignant *breast mass* is identified at P.E., X.M. is once more required for the following reasons: α) the *multifocal breast cancer* could be demonstrated very often only with X.M.; the information compels one to re-

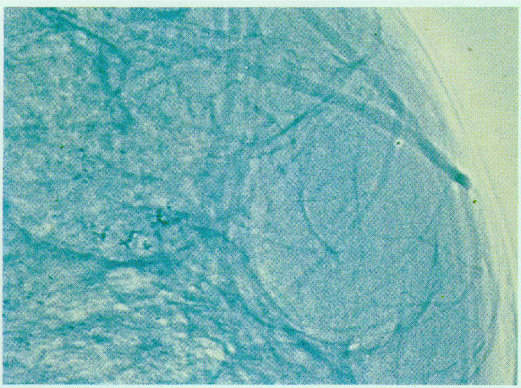
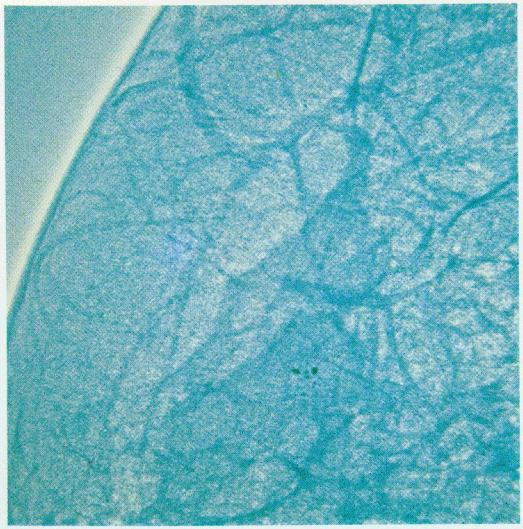


Fig. 1. Microcalcifications without neoplastic nodule (invasive ductal carcinoma, asymptomatic to P.E.).



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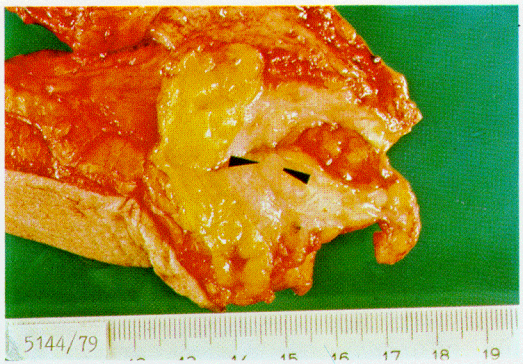


B

Fig. 2 A-B. A) Invasive ductal microcarcinoma in the upper part of the left breast; no evidence at P.E. B) Surgery specimen.

nounce the conservative treatment of a small breast cancer; β) the *controlateral simultaneous breast cancer (9.2%* in the personal experience) often could be demonstrated only by X.M., because the second controlateral tumour is usually smaller than the first one; also in this evenience, the treatment planning is completely modified.

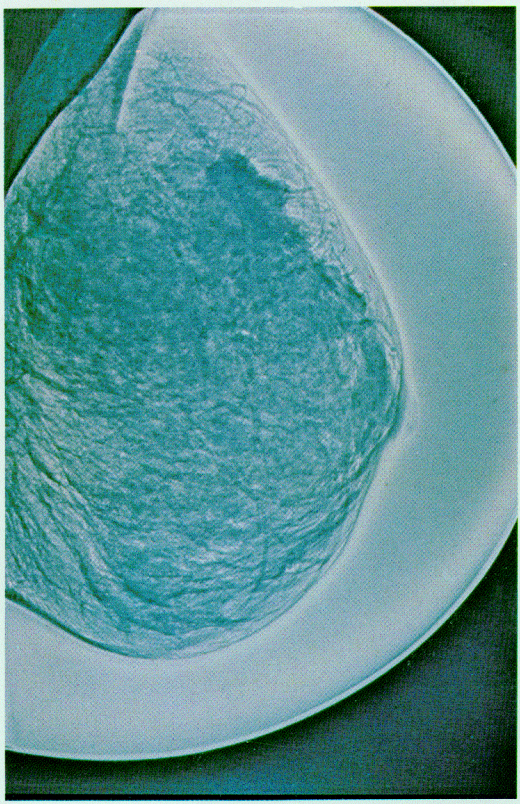


Fig. 3. Ductal carcinoma included in a very dense dysplasic area.

Fig. 4. Pagel's carcinoma of the nipple. Behind the areola thin branches with microcalcifications.

3. The contact thermography was the complementary method constantly utilized in the diagnostic approach in this series. The reason of this association is based on the difference between the instrumental investigations (mammography, echography, breast trans-illumination) which document the morphological pattern of the lesion and on the other hand, the thermographic investigation, which detects the metabolic modifications of the tumour. This difference explains the following indications of C.T.: a) diffuse *type* of breast cancer: in this case, the clinical (P.E.) and morphological (X.M.) alterations may be absent or anonymous; β) tumoural nodule less than 5 mm in *diameter* γ) tumoural nodule hidden in a fibrous magma (i.e., breast fibro-dysplasia); δ) malignant nodule with *benign morphological,feat~~re~* (Fig. 5).

CI THERMOCRAPHIC PATTERNS OF BREAST CANCER

Breast cancer C.T. signs are essentially based on several alterations of the vascular network. The following patterns may be distinguished:

a) Focal neo-vascularisations, with irregular distribution of the vessels. This pattern corresponds, from the haemodynamic point of view, to the tumoural artero-venous fistula, with both the supplying arteries and the draining veins enlarged (Fig. 6). This neo-vascularisrtion may take different appearances, like «tumoural star» (Fig. 7) (many vessels converging to and diverging from tumoural nodule: wheel - spoke pattern) or like «peri-tumoural vascular ring» (the tumoural nodule is encircled by an enlarged circular vessel) (Figs. 8, 9).

p) Anomalies of one or more branches of the breast vascular tree. They are mainly represented by: enlarged diameter of the main branches; fragmentation and/or vascular cut-off of the main branches; club-like deformation of the terminal branches (Figs. 10, 11, 12).

γ) *Non vascular anomalies* of the breast C.T. They are represented by a single «hot spot», the whole breast background as well as the nipple hyperthermia (Fig. 13).

The C.T. study of the breast must include the functional challenge test based on the cooling of the skin surface. After the cooling, both

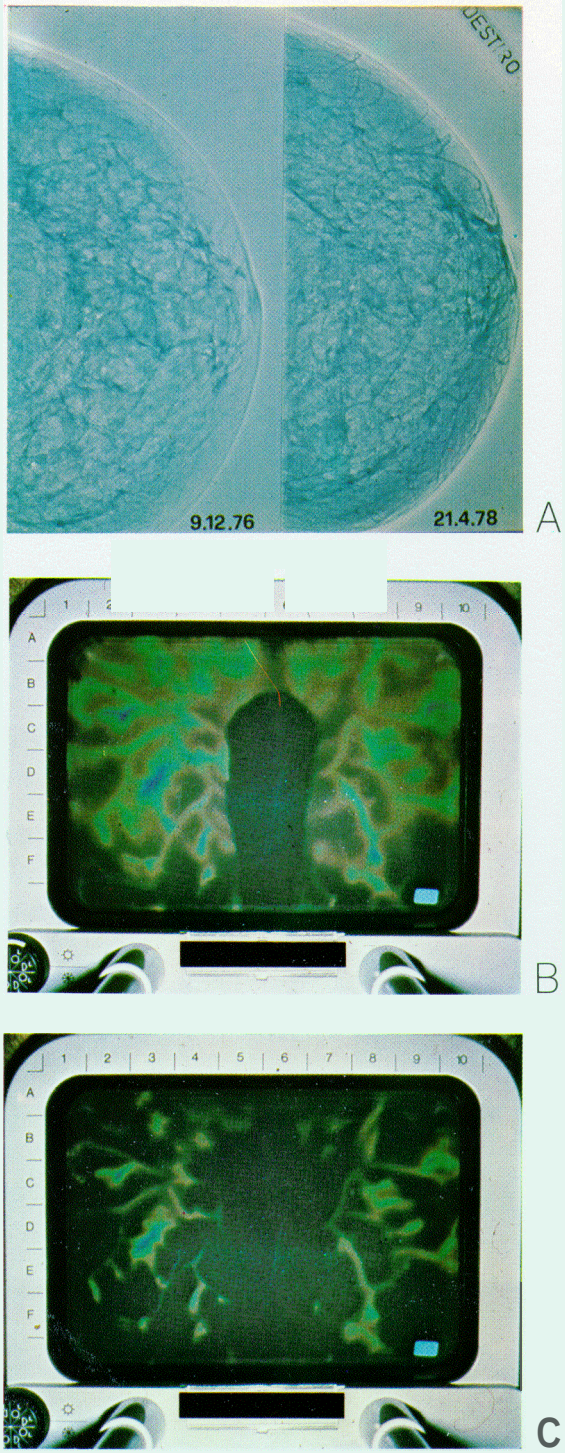


Fig. 5 A-C. A) Benign-iookmg nodule of the right breast, with sharp borders. A control at 16 months showed slight increase (ductal carcinoma). B) Hyperthermic vessel with greatly increased diameter and irregular walls. C) Early reappearance of the pathologic vessel following cooling.

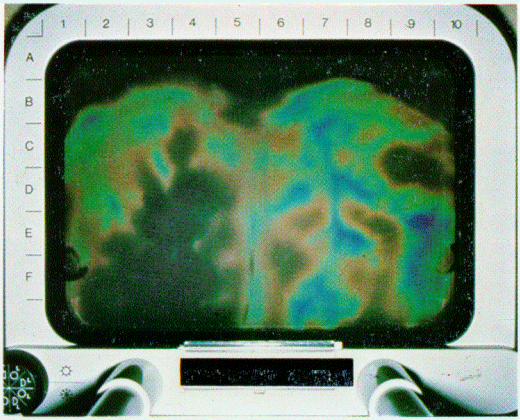


Fig. 6. Notable hyperthermia and hypervascularisation of the left breast, slightly increased in consistence (non infiltrating comedocarcinoma).

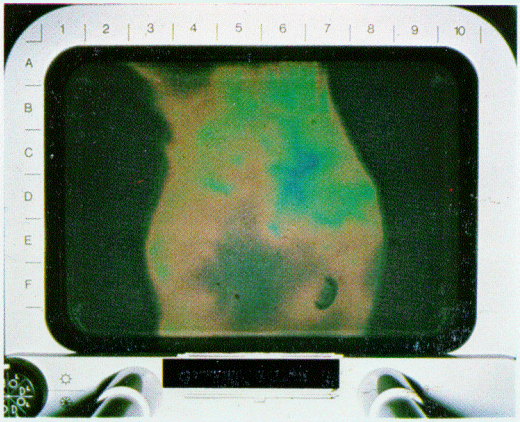


Fig. 7. Hyperthermic vascular star (ductal carcinoma).

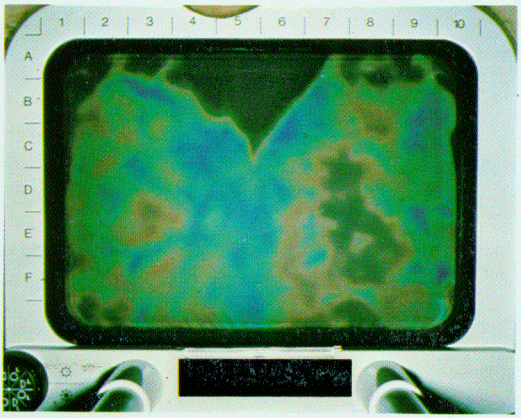


Fig. 8. Tumoural nodule surrounded by a hyperthermic vascular ring from which vascular branches start for the internal mammary vein.

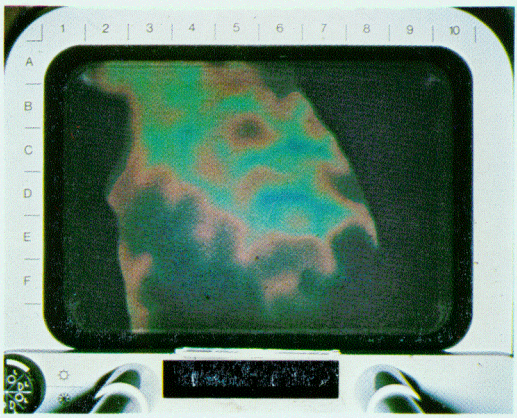
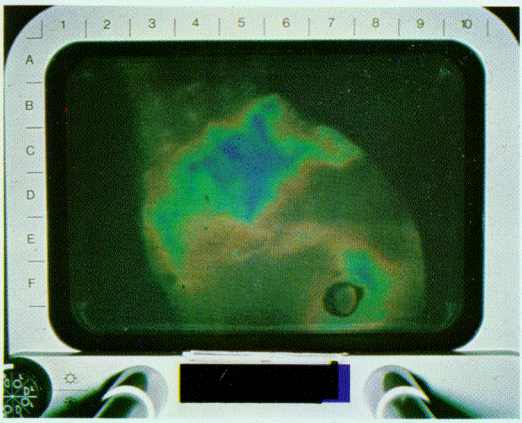


Fig. 9. Vascular ring with penetrating vessels around the tumoural nodular focus (ductal carcinoma).



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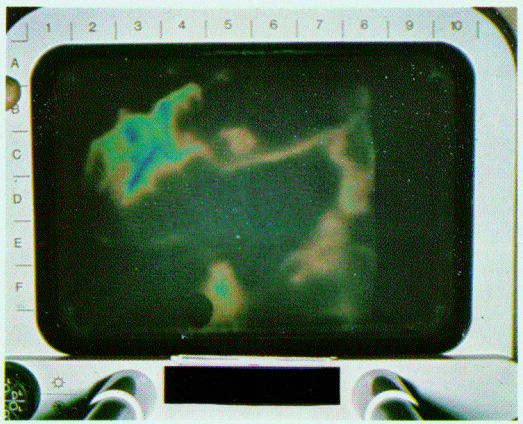

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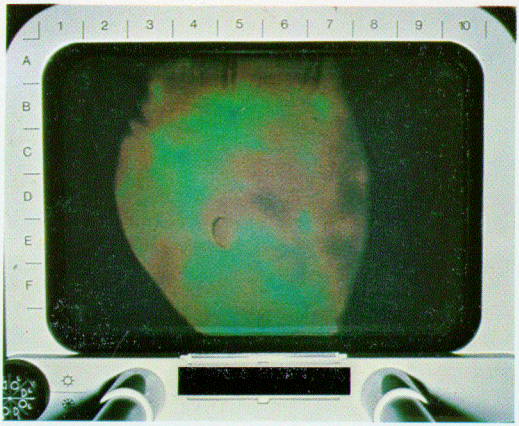
Fig. 10 A-B. A) Greatly hyperthermic area above a large dysplasic zone covering the neoplasm (ductal carcinoma) B) After cooling, the hyperthermic area is constituted by large irregular and converging vascular branches.



A

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Fig. 11 A-B. A) Hypervascularisation in the external mammary and acromioclavear region. B) Early reappearance of a hyperthermic «club-like» vessel, after cooling.

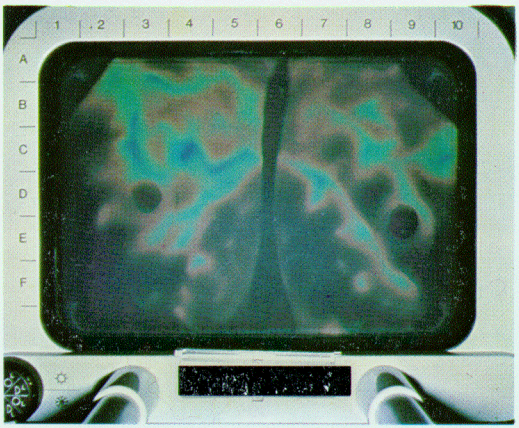


Fig. 12. Non complete ring made of hyperthermic «club-like» vessels (ductal carcinoma).

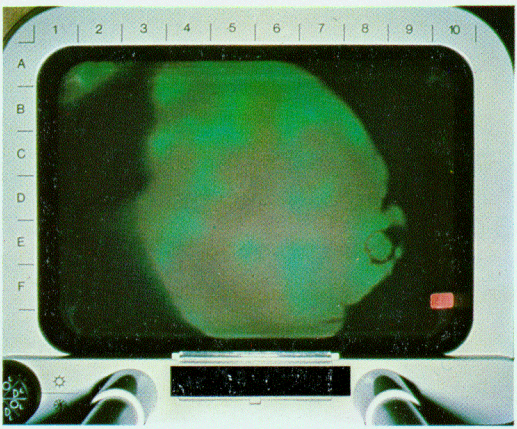


Fig. 13. Hot nipple and background heat increase, persisting after cooling (inflammatory carcinoma of the right breast)

normal and abnormal vascular C.T. images disappear, but the last ones appear again sooner than the normal vascular network.

D) RESULTS

The comparative efficacy of P.E., X.M. and C.T. has been evaluated in the present series of 198 breast cancers.

1. Accuracy of xero-mammography and contact thermography according to the age of the patient (Tab. I)

The accuracy of the X.M. in the present series was not influenced by the age of the patients, although usually the mammographic results in the dense breast of younger women are just less satisfactory than those in the «empty» breast of the elder women. This fact could depend from the more favorable resolution power of X.M. versus mammography. On the contrary, C.T. accuracy appeared to decrease in the age group over 60 yrs, being the breasts of old women rich in fat tissue, which is a bad heat conductor.

2. ACCuracy of contact thermography according to the tumour size (Tab. II)

On this purpose, the C.T. findings were referred to the size evaluation, obtained by X.M. As tumour size increased, C.T. accuracy be-

Tab. I. **Accuracy of xeromammography and thermography according to age.**

Age	N. of cases	Accuracy	
		Xeromammography	Thermography
39	20	18/30 (95%)	16/20 (80%)
40-44	18	18118 (100%)	1511 8 (83%)
45-49	24	22124 (91.5%)	19124 (79%)
50-54	26	26126 (100%)	18/26 (69%)
55-59	28	27128 (96.5%)	26128 (92.5)
60	82	82182 (100%)	64182 (78%)
Total	198	1931198 (97.5%)	1581198 (79.8%)

Tab. II. **Contact thermography accuracy according to tumour size.**

Tumours diameter	C.T. accuracy
> 5 mm	66.6%
6-10 mm	73.3%
11-29 mm	74.1%
< 3 0 m m	93.2%

Tab. III. **Contact thermography accuracy according to the radiologic pattern of the tumour.**

Radiological pattern	C.T. accuracy
Wheel-spoke nodule	73%
Lobulated nodule	84.5%
Round nodule	85.5%
Microcalcification without nodule	83.3%'

comes higher, starting from 66.6% in tumours less than 5 mm in diameter to 93.2% in tumours more than 30 mm in diameter. It is necessary to keep in mind this finding where a screening program is based on thermography - whatever method is chosen .since it must be foreseen that an important part of the silent tumours are of small size and therefore the false negative rate of C.T. will be high. Finally, the high C.T. accuracy in all the T4 breast cancers (94.7% in the personal series) must be emphasized.

3. Accuracy of contact thermography according to the radiological pattern of the tumour (Tab. III)

It is well known in the thermographic Literature that breast cancers of the scirrhous type are more frequently hypothermic. The personal C.T. findings confirm this figure, being the C.T. accuracy only of 73% in this type of tumours. In the other types of breast cancer (lobulated or round nodule) the C.T. accuracy is higher, being about 85%. Nevertheless, the most important contribution of C.T. to the diagnosis of breast cancer is related to the high accuracy obtained when the tumoural nodule is not appreciable at X.M. examination, when it is of the diffuse type or when it is hidden in a fibrous inagma. In both cases, the X.M. diagnosis was based on typical microcalcifications.

E) DISCUSSION

In the personal series (198 breast cancers) the accuracy of each method was as follows: it was 86.9% in P.E. examinations (172/198), 97.8% in X.M. examinations (193/198) and, finally, 79.8% in C.T. examinations (158/198).

The role of the association of C.T. to the two fondamental examination methods of the breast (that is the P.E. and X.M. examinations) was evaluated (Tab. IV).

Tab. IV. **The diagnostic gain in the different methods association.**

Method	Accuracy of single method	False negative case	Diagnostic gain with C.T.	Accuracy of association with C.T.
P.E.	172/l 98 (86.9%)	26/l 98	17/26	189/198 (95.5%)
X.M.	193/i 98 (97.5%)	5/1 98	315	196/198 (99.0%)

1. Xero-mammography and contact thermography association

Although X.M. accuracy has been very favourable (97.8%), nevertheless-the X.M.-C.T. association reduced the false negative rate from 2.5% to 1.O%, since 3/5 X.M. false negative cases were correctly identified by C.T. Consequently the accuracy of X.M. C.T. association rose up to 99.0%.

2. Physical examination and contact thermography association

The diagnostic gain achieved by C.T. examination when combined to P.E. was very important. In fact, in this evenience the P.E. false negative rate fell from 13.1% to 4.5%, being 17/26 P.E. false negative cases correctly identified by C.T. This result is very interesting in the better clinical approach to non symptomatic women in which the combined use of P.E. and C.T. may be proposed according to lower cost of this association in comparison with the association P.E. and X.M.

Mammography and contact thermography for the diagnosis of breast cancer: a combined approach

by G. VIGANOTTI,[1] S. BERGONZI,[1] R. NESSI,[2] S. COSTA,[2] and I. MACCHI[2]

[1] Department of Radiology, National Cancer Institute and [2] Institute of Radiology, University of Milan, Milan (Italy)

Summary. Mammography (M.) and Contact Thermography (C.T.) were performed jointly on 210 operated breast cancers, confirmed by histology. The advantages and drawbacks of each method are outlined and discussed, and their diagnostic accuracy is considered according to the different anatomical and histological conditions. C.T. examinations is held to be a reliable adjunctive diagnostic procedure in breast cancer when associated with the M. examination.

Key words: thermography, mammography, breast cancer.

A) INTRODUCTION

The prognosis of breast cancer is still strictly related to its early detection, in spite of all the therapeutic improvements reached insofar. In addition, only in small cancers (less than 2 cm in diameter), it is possible to undertake conservative treatments with a good success under

both the psychological and oncological points of view. The need for an early detection of breast cancer is then mandatory and for this purpose it is necessary to use all the available technical resources. alone or in association.

1. The **physical examination** (P.E.) must be considered, of course, the basic diagnostic step before any further investigation. It carries, however, a relevant possibility of error, even if it is performed by a skilled physician.[2] On the other hand, the P.E. examination alone is unable to specify in details the exact size and the metabolic potential of the tumour. These data can be outlined if mammography (M.) and thermography (T.) are performed in association.'

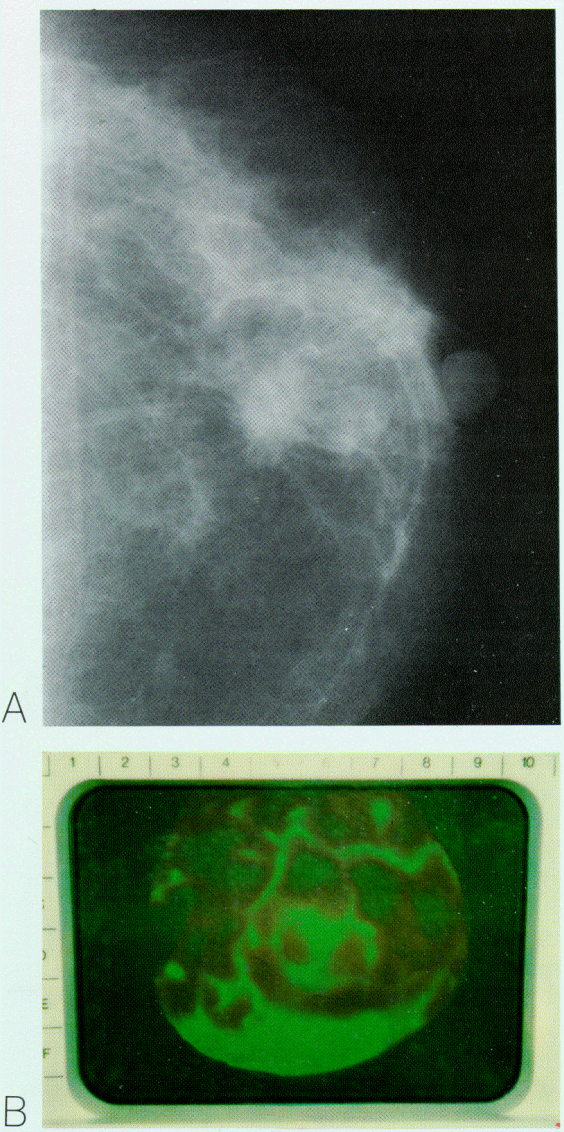
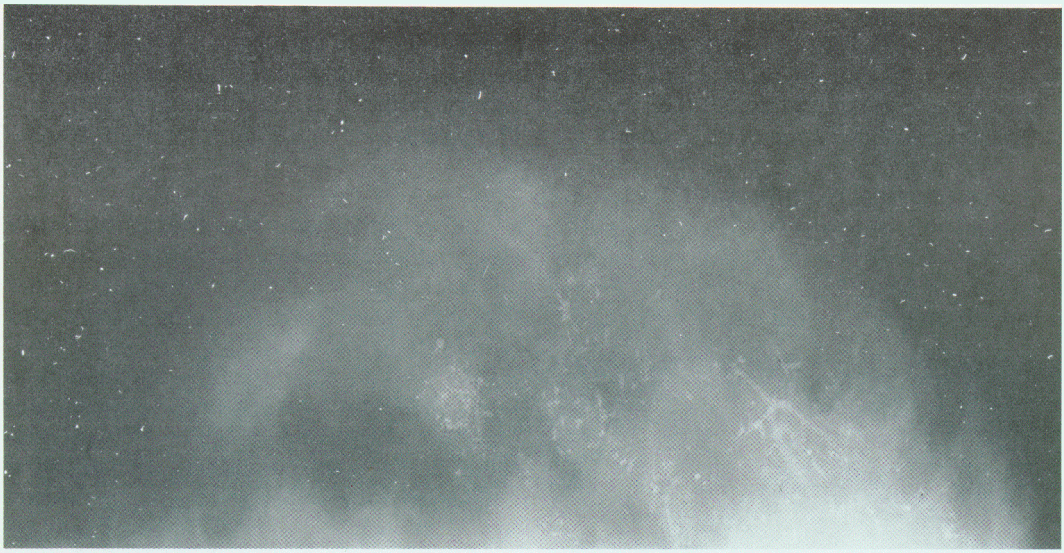


Fig. 1 A-B. Retro-areolar scirrhous carcinoma. A) No venous engorgement at M. examination. B) Persisting vascular anomalies after cooling dynamic test at C.T. examination.

2. If properly performed **mammography** (M.) seems suitable for the study of the size and of the site of the tumoural mass, together with the state of the surrounding tissues and of the overlying skin (Figs. lA, 2A, 3A). Sometimes, the M. examination may identify a breast cancer, also in absence of palpable nodule, when typical micro-calcifications are detectable (Fig. 4A). The effectiveness of M. is highest in large adipose breasts, disclosing here easily palpable cancers. The M. examination is also very useful for the follow-up of the breast submitted to conservative treatments and for the surveillance of the controlateral breast after mastectomy." The advantages of the M. examination as a specific diagnostic procedure in selected patients are by far overwhelming its drawbacks related to its supposed oncogenicity; in particular, it must be kept in mind that the film-screen combination in the more recent M. technique does strongly reduce the radiation dose to the patient.

It must be stressed, therefore, that in the personal opinion the M. examination is not considered, as a first line screening procedure. There are, however, some intrinsic limits of M., in particular in dense breast, where small cancers (Tl) can remain undetected. As it is well known, breast opacity can be due either to hyperplasia or to mastoplasia of the parenchima; the first condition is typical of the juvenile breast, the second one is more frequent in pre-menopausal women.[3]

3. The aim **of thermography,** which was introduced in medical practice as dynamic T. at first, is to detect hyperthermic areas (significant AT $\geqslant$ 2 "C: Fig. 2 B) and/or vascular anomalies (Figs. 1 B, 3 B, 4 B). Both findings are frequently associated with an underlying cancer. It must be remembered, anyway, that the T. results depend upon the metabolic behaviour of the cancer, not providing any information about the morphology and side of the tumoural mass. The latter data can be evaluated



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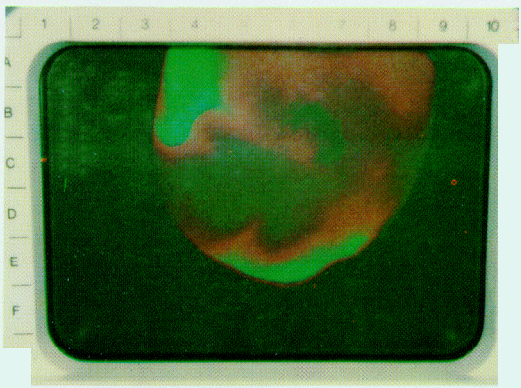

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Fig. 2 A-B. Comedo-carcinoma of the lower-outer quadrant. A) Typical calcifications at M. examination. B) Hyperthermia of the sub-mammary sulcus.

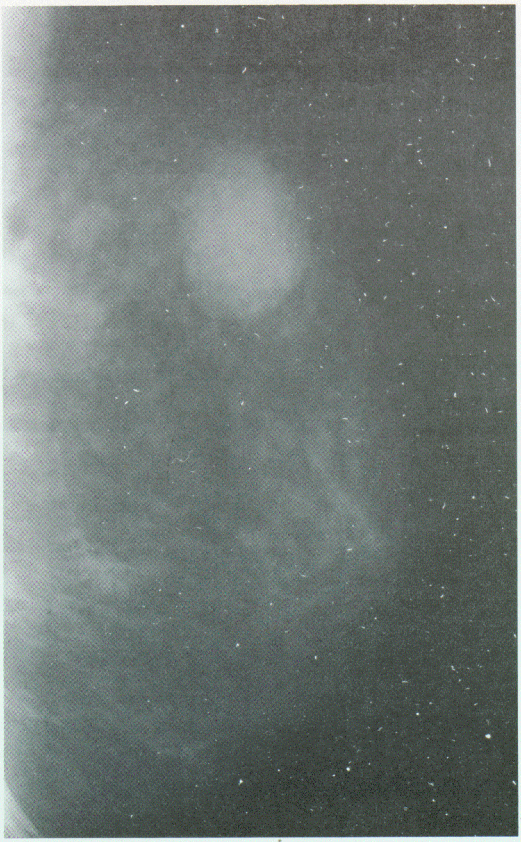
by the M. examination, which must be therefore associated with T. in any suspect case. Since T. is a non-irradiating and non-invasive procedure, it may be repeated freely, being for this reason very useful in the serial control of high risk women or in the follow-up of the treated patients. The contact thermography examination (C.T.) is the more recent technique in use. The most important advantages of C.T. are the low cost of the whole apparatus and the independence from the use of a conditioned room, which is, on the contrary, mandatory in infra-red T. (I.T.). The overall C.T. examination is a little more time-consuming than I.T. examination and it has to be performed by the physician himself. This is however in agreement with a correct clinical approach to the patient. From a diagnostic point of view, C.T. allows a good evaluation of the vascular network" but the appreciation of focal hyperthermias is reduced, since the 2 breasts are examined separately. The diagnostic criteria of C.T. are rather complex and there are some controversies in particular as minor vascular abnormalities are concerned. Finally, the proper contact between the C.T. plate and the skin can be impaired in the infra-mammary sulcus and when surgical scars are present.

B) RESULTS

The C.T. examination of the breast is currently used at the National Cancer Institute of Milan, since 3 yrs.

1. A **clinical trial** is now in progress in order to establish the accuracy of C.T. and of its association with the M. examination. The C.T. and M. examinations were performed when P.E. suspected a malignant lesion. All the patients subjected to this trial were surgically and histologically controlled. At this moment, 210 women have been evaluated this way, being their breast cancers small or middle sized (less than 50 mm in diameter).

2. For the M. examination, the **following criteria of malignancy** were considered: a dense nodule with irregular or poorly defined borders; one or more clusters of microcalcifi-



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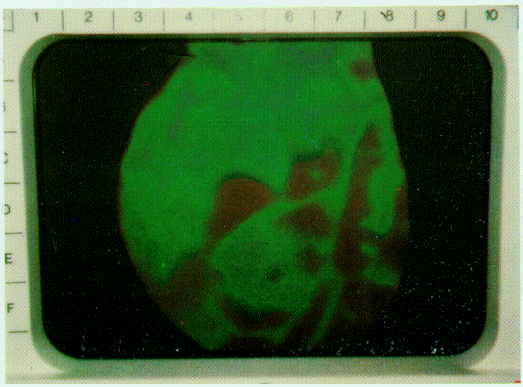
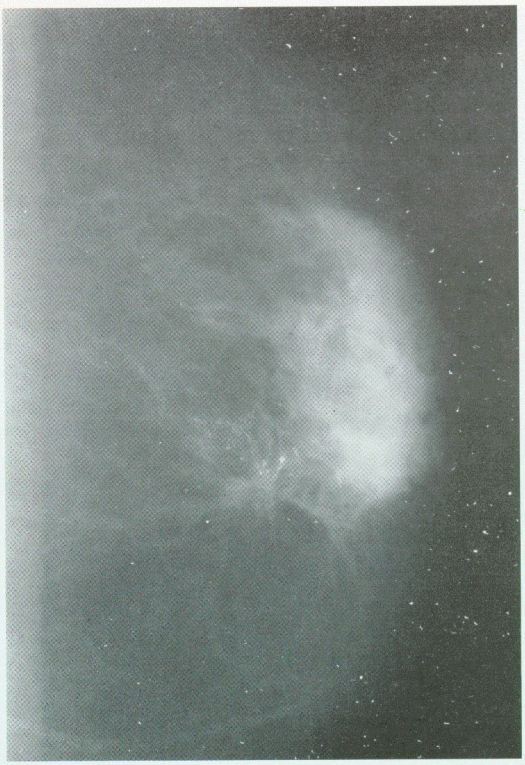


B

Fig. 3 A-B. Medullary carcinoma of the upper breast. A) Nodule with sharp border and no peri-tumoural venous engorgemcnl at M. examination. B) Diffuse vascular anomalies at C. 1'. examination.



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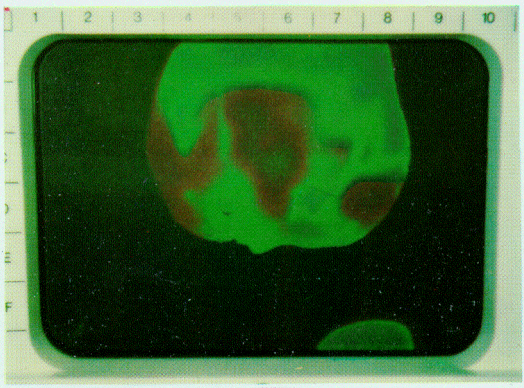

B

Fig. 4 A-B. Central breast cancer without nodule. A) Typical malignant calcifications at M. examination. B) Vascular anomalies and nipple hyperthermia.

cations; peri-tumoural oedema or phlebectasia; skin thickening or retraction.

For the C.T. examination the following criteria of malignancy were considered (Figs. 1 B, 2 B, 3 B, 4 B): a hot spot; vascular anomalies (tumour star; tumour ring); nipple hyperthermia.

These C.T. signs were considered significant only when persisting after the cooling test, performed with the C.T. plate still placed on the breast: this way, also the time of disappearante of the vascular image can be evaluated. The most typical signs of malignancy have

been the vascular anomalies, while nipple hyperthermia, although strongly suggestive for malignancy has been seldom observed. No vascular cut-off sign has been found, although sometimes reported by the Literature.'

3. The **accuracy** of each diagnostic method in this series of 210 breast cancers has been as follows: in the P.E. examination, 191/210 (91%); in the C.T. examination, 1931210 (92%); in the M. examination, 199/210 (95%). The association of the C.T. (Tab. I) and the M. examination (Tab. II) to the P.E. examination allowed to eliminate the false negative rate, reaching the 100% of certain or suspect diagnosis of malignancy. The C.T. and M. examinations can be considered complementary, since C.T. helps to correct the few M. errors (Tab. III).

a) There was a direct relationship between *tumoural size* and diagnostic accuracy. In smal-

Tab. I. **Comparison between physical examination and contact thermography.** (210 breast cancers).

C.T. \ P.E.	Malignant	False negative	Suspect	Total
Malignant	175	6	12	193 (92%)
False negative	14		1	15 (7.1%)
Suspect	2	–	–	2 (0.9%)
Total	191 (91%)	(2.8%)	13 (6.2%)	210 (100%)

Tab. II. **Comparison between physical examination and mammography.** (210 breast cancers).

M. \ P.E.	Malignant	False negative	Suspect	Total
Malignant	182	6	11	199 (94.8%)
False negative	4	-	-	4 (1 .9%)
Suspect	5	-	2	7 (3.3%)
Total	191 (91%)	(2.8%)	(6.2%)	210 (1 00%)

Tab. III. **Comparison between contact thermography and mammography.** (210 breast cancers).

M. \ C.T.	Malignant	False negative	Suspect	Total
Malignant	184	13	2	199 (94.8%)
False negative	4		-	4 (1.9%)
Suspect	5	2	-	7 (3.3%)
Total	193 (92%)	15 (7.1%)	(0.29%)	210 (1 00%)

ler tumours (less than 2 cm in diameter) M. is more effective, while larger tumours (4-5 cm in diameter) are more exactly (up to 100%) diagnosed by C.T. (Tab. IV). This peculiar finding has already been reported.[4]

b) The relationships between the *histotype,* in prevalence (67%) scirrhous,[7] and diagnostic accuracy of each method were summarized in Tab. V. As to the M. examination the highest accuracy (100%) was achieved in the multiple histotype tumour, in the plurifocal tumours and in the medullary carcinoma; the middle accuracy in the scirrhous carcinoma (93.5%) and in the lobular carcinoma (89%), whereas the lowest accuracy was achieved in the various types of tumours (83%).

As to the C.T. examination, the highest accuracy was noticed in lobular and medullary

Tab. IV. **Diagnostic accuracy according to the sine of tumours.** (210 breast cancers).

Tumours size	N. cases	Malignant patterns	
		Mammography	Contact thermography
' 2 c m	10	*9/10 (90%)*	*7/10 (70%)*
3 cm	*87*	*83/87 (95.4%)*	*77/87 88.5%)*
4 cm	*68*	*67/68 (9 8 . 5 %)*	*61/68 (89.7%)*
5 cm	*27*	*25/27 (92.6%)*	*27/27 (100%)*
5 cm	*18*	*18/18 (1 00%)*	*18/18 (1 00%)*
Total	*210*	1991210 *(95%)*	*1931210 (92%)*

Tab. V. **Diagnostic accuracy according to the histotype of tumours.** (210 breast cancers).

Tumours histotype	N. cases	Contact thermography	Mammography
Scirrhous carcinoma	*141 (67%)*	*133 (94%)*	*132 (93.5%)*
Multiple histotypes	(17%)	(86%)	(100%)
Plurifocal	(7%)	(86%)	(100%)
Various	(3%)	(67%)	(83%)
Lobular carcinoma	(2%)	(1050%)	(1 0 5 0 %)
Medullary carcinoma	(2%)	(100%)	(100%)
Total	*210*	*193/210 (92%)*	*199/210 (95%)*

carcinoma (100%), the middle accuracy was noticed in scirrhous carcinoma (94%), in the plurifocal tumour (86%) in the multiple histotypes tumour (96%); the lowest accuracy was noticed in various types of tumours (67%). Being the scirrhous histotype the most frequent one, the accuracy of C.T. and M. examination seems to be the same (94% versus 93.5%).

c) Finally, there were no significant correlations between the C.T. positive findings and the *metastatic involvement.* This finding does not allow, at the moment, to utilize the C.T. results as a prognostic factor of the tumours.

CI DISCUSSION

The present trial is still iri progress but, from this preliminary evidence, some tentative considerations can be drawn:

1. The **diagnostic accuracy** of the C.T. examination, even if scantly lower than of the M. examination, is very high, also for small cancers, and increases in a linear fashion with the increase of the tumoural size, while this behaviour is not evident in the M. examination.

2. There are no **correlations** between the: morphological feature of breast cancer at M. examination and the thermo-vascular behaviour at C.T. examination (Figs. 1, 3).

3. The accuracy of each method is not influenced in the same way by the **histotype.** In fact, in the plurifocal tumours and in the multiple histotypes tumours the accuracy of the M. examination was higher than that of the C.T. examination: for the second type of tumour, this result can be explained by the different malignancy of the several histological components.[7]

In conclusion, these preliminary results confirm the diagnostic reliability of C.T. in breast cancers. Taking into account its drawbacks and limits, however, C.T. cannot be proposed as the unique investigation when a tumour is suspected but it must be always associated to the M. examination.

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