ACTA THERMOGRAPHICA

Volume 1 Book 1

Content

Correlations between thermography and morphology of primary cutaneous malignant melanomas

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SUMMARY. Of 30 malignant melanomas 27 (90%) had positive thermal gradients, varying from + 1°C to 4°C. These thermal gradients do not correlate with the histogenetic type, nor the cell type, nor the mitotic activity, nor the lymphocytic infiltrate (neither at the in situ portion nor at the invasive portion), nor, finally, with the level of invasion, even if all the neoplasias at the 5th level show a thermal gradient of 3°C. However there is clear correlation with the TNM clinical stage.

Key words: thermography; cutaneous malignant melanoma; anatomo-clinical comparison.

Introduction

The prognosis for cutaneous malignant melanoma seems to be related to its histologic characteristics ([12]), and to the cellular, humoral, and specific antitumoral immunity of the patient ([10, 15]).

Melanoma is a biologically complex and unpredictable neoplasia as can be seen from the documented spontaneous regression ([13]), its great ability to metastasize early, and the long periods of remission even in cases in advanced clinical stages.

The success of antimelanoma therapy appears to depend on early clinical and histological diagnosis, but this is made difftcult, because of the existence of lesions that are morphologically and histologically similar to melanomas. Thermography of pigmented tumors is a useful, easy to use, and innocuous diagnostic method.

In the majority of cases malignant melanomas present as warm areas. This warmth may be directly proportional to invasiveness of the neoplasia ([9]).

The purpose of this work is to analyse the thermographic data of 30 malignant cutaneous melanomas in a comparison with their respective morphologic characteristics, and to search for possible significant correlations.

Material and methods

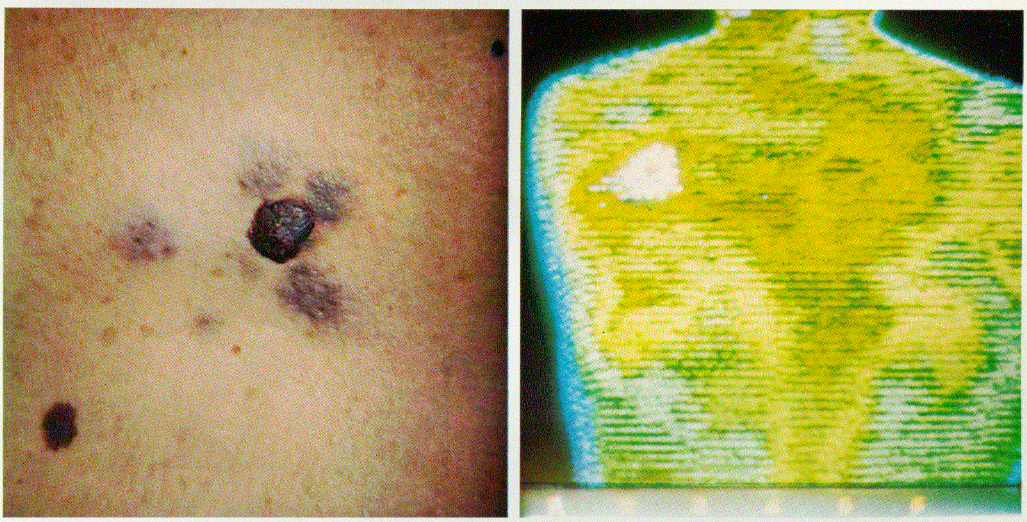
The thermograms were taken with a Bofors I R Mark 3 camera. The thermal gradient was evaluated by comparing the increased warmth of the lesion with the ‘warmth of the surrounding skin. It was recorded in degrees Centigrade (+1°C +2°C, +3°C, and +4°C). The thermograms were taken in black and white and in color. With ulcerated lesions, the cold area corrisponding to the ulcer was not considered and only the surrounding thermal gradient was evaluated. The age and sex of each patient was considered. With each neoplasia we recorded its clinical appearance, its TNM grade ([5]), the possible pre-existence of a nevus, and the duration and description of the presenting complaints (bleeding, changes in color, enlargement or ulceration of the lesion, and pain).

The specimens were fixed in buffered formalin and the sections were stained with hematoxylin-eosin, Alcian blue-PAS, and Weigert-Van Gieson.

Analysis for melanin was done with the

A B

Fig. 1. Case 3. A) Right foot: nodular melanoma. B) Thermogram: cold area (ulcer) surrounded by intense (+3°C) hyperthermic halo.



A B

Fig. 2. Case 13. A) Back: invasive melanoma with adjacent intra-epidcrmal component of superficial spreading type; subcutaneous metastases. B) Thermogram: very warm (+3°C) white area.

method of Fontana-Masson. It was always differentiated from hemosiderin by Tumbull's Blue method.

In one case. excision of the tumor was done at autopsy because when the patient was first seen, the neoplasia had 50 highly metastasized that excision was considered deferrable. Therefore in this case the mitotic activity was not considered.

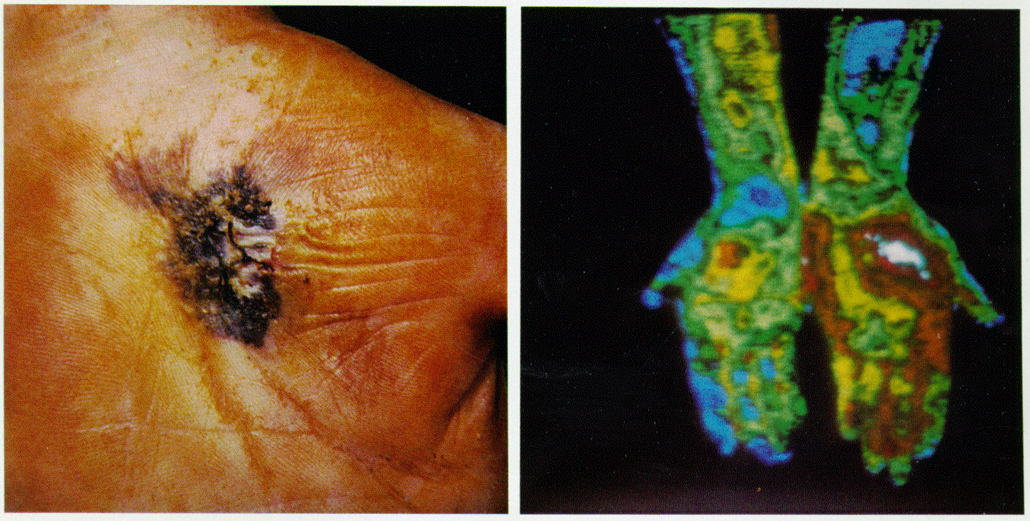
The malignant melanomas were classified according to the terminology recommended by McGovern et al. ([14]).

In each case we examined:
1) the site;
2) the overlying epidermis;
3) the level of invasion, described according to the criteria reported by Clark et al. [3,4];
4) the cell type of the malignant melanocyte, distinguishing between epithelioid, spindle, and anaplastic;
5) the mitotic activity, evaluated according to the grades (1,2,3) reported by McGovern et al. [14];
6) the lymphocytic infiltrate at the level of the invasion and its eventual adjacent intra-epidermal component was evaluated as:
   a) absent;
   b) slight: characterized by sparse accumulation of lymphocytes and plasmocytes usually localised at the margins of the lesion;
   c) moderate: the immune reaction is observed as a broken barrier usually peripheral to the lesion;
   d) intense: a complete barrier of lymphocytic infiltrate entirely surrounds the melanoma.

Results

In this series of cases there was a prevalence of females (60%) over males. Incidence was highest (23,3%) between 50 and 59 years of age. The most common sites were on the limbs (53,3%), usually the lower (75%) rather then the upper limbs. Eighteen patients (60%) had case histories of a nevus from the time of birth. In four patients the nevi appeared in later years. The symptoms varied in duration from 7 years to 15 days, with the highest incidence from 1 to 6 months (56.6%). The classification of the melanomas, is this series, in clinical stages according to the TNM system, showed a slight prevalence of the T2's (40%) over T3's (33,3%). There were 2 cases that had already metastasized at the time of diagnosis: one to regional lymph nodes, another diffusively.

The epidermis overlying the lesion ap-



A B

Fig. 3. Case 22. A) Left palm: invasive melanoma with adjacent intraepidermal component of superficial spreading type. B) Thermogram: comparision of the palms clearly shows the hyperthermic area (+2°C) on the left.

Table I.

	N°	Name	Biopsy N°	Age	Sex	Site	Pre existent nevus	Duration of symptoms in months	Over lying epidermis	Clinical stage TNM	Histogenetic type	Level invasion	Cell type	Mitotic activity	Lynphocytic infiltrate: In situ component	Lynphocytic infiltrate: Invasive component	Thermal gradient
	1	C.M.	46604	70	M	Abdomen	B	3	LJ	T 2	IM+SSM	3	S	3	M	A	1°C
	2	G.P.	30534	49	F	R. Face	B	1	A	T 1	SSM In situ	1		1	I		1°C
	3	B.A.	30299	43	F	R. Foot		24	U	T 3	N M	5	S	2		A	3°C
	4	M.A.	16604	59	M	Back	B	3	A	T 2	IM+SSM	3	S	3	I	S	3°C
	5	F.O.	21469	67	F	R. Thumb		3	U	T 3	NM	5	E	1		A	3°C
	6	F.M.	32269	33	M	Face Chin	B	1	H	T 1	IM+SSM	2	E	3		S	1°C
	7	C.S.	21581	59	F	L. Foot		84	H	T 3	NM	2	E	1	I	I	3°C
	8	P.F.	36859	63	F	Face	B	5	U	T 3	NM	3	E	1		M	3°C
9	9	F.C.	15315	37	M	Face	B	4	H	T 2	IM+SSM	3	E	3	S	A	3°C
	10	V.R.	36896	89	F	Face	B	12	U	T 3	NM	5	E	3		A	3°C
	11	B.P.	33050	74	F	Face	B	2	A	T 1Nlb	IM+SSM	2	E	1	I	I	3°C
	12	C.T.	37371	56	F	R. Foot	B	1	U	T 2	NM	3	E	2		A	1°C
	13	Z.D.	1001	50	M	Back	B	2	u	T 3 M 1	IM+SSM	4	E		S	A	3°C
	14	F.M.	12638	19	F	R. Forearm	B	8	U	T 2	IM+SSM	3	E	2	I	A	3°C
	15	C.I.	18305	49	F	R. Thigh	B	24	U	T 2	IM+SSM	3	E	1	S	A	3°C
	16	M.D.	44598	20	F	Neck	B	7	A	T 1	SSM In situ	1		1	I		1°C
	17	R.C.	17385	50	F	R. Leg	B	6	A	T 3	NM	5	A	1		A	3°C
	18	O.L.	40358	65	M	R. Palm		24	U	T 3	NM	3	A	2		A	4°C
	19	M.C.	45751	52	F	L. Leg	3Yrs	2	A	T 1	IM+SSM	2	E	1	I	A	0
	20	B.C.	43172	47	F	L. Leg	B	7	H	T 2	IM+SSM	3	E	1	S	A	0
	21	A.C.	42498	47	F	L. Leg	1Yrs	6	H	T 3	NM	4	E	2		A	3°C
	22	C.S.	42058	54	M	L. Palm	5Yrs	1/2	H	T 2	IM+SSM	3	E	3	I	A	2°C
	23	R.B.	26759	68	M	Face		4	U	T 2	NM	4	E	3		M	2°C

24	G.C.	36889	71	M	Face		6	A	T 1	HMF	1		1	I		2°C
25	R.A.	37055	70	M	L. Foot	B	2	H	T 2	NM	4	A	3		A	O
26	R.A.	38418	77	M	L. Foot		36	U	T 3	IM+SSM	4	E	3	S	A	3°C
27	N.M.	47950	64	M	Abdomen	B	2	A	T 2	IM+SSM	3	E	3	I	S	1°C
28	D.L.	47951	36	F	R. Leg	B		H	T 1	NM	2	E	1		M	1°C
29	P.C.	24703	72	F	Face L.		1	A	T 2	IM+HMF	4	S	1	I	A	3°C
30	P.A.	26871	37	F	L. Leg	9Yrs	48	U	T 1	NM	3	S	2		S	1°C

B = nevus from Birth
Yrs = nevus from Years

U = Ulcerated
A = Atrophic
H = Hyperkeratosis

SSM = superficial spreading melanoma
IM+SSM = invasive melanoma superficial spreading Type
NM = nodular melanoma
HMF = Hutchinson's melanotic freckle
IM+HMF = invasive melanoma Hutchinson's melanotic freckle Type

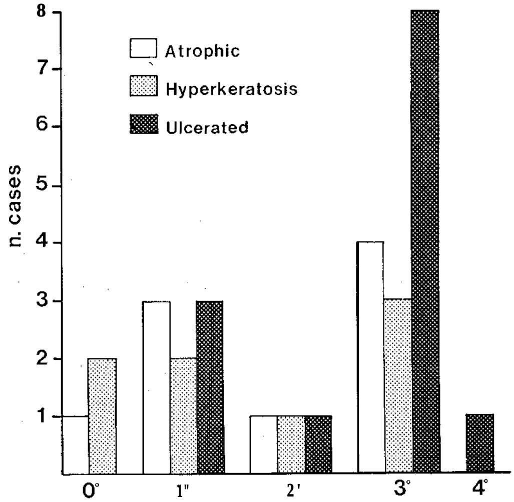
S = Spindle
A = Anaplastic
E = Epithelioid

I = Intense
S = Slight

A = Absent
M = Moderate

peared ulcerated in 13 cases (43,3%). It was atrophic [7] in 9 (30%), and hyperkeratosic in 8 cases (26,7%).

The histogenetic types that were most highly represented were the nodular melanoma and the invasive melanoma with adjacent intra-epidermal component of superficial spreading type (43,3%).



Graph. 1. Correlation between thermal gradient and overlying epidermis.

The most common level of invasion was the third (40%), where the most prevalent type was the invasive superficial spreading melanoma. The nodular type (30,7%) invaded to the 5th and 3rd levels with an equal incidence (40%).

The rare' in situ types (1 Hutchinson's melanotic freckle, 2 superficial spreading noninvasive melanomas) all showed intense lymphocytic infiltrate, but these infiltrates diminished in direct relationship to the level to which the tumor invaded. In fact, independently of the histogenetic type, the infiltrates were always absent in forms that reached level 4 or 5.

For invasive melanomas with adjacent intra-epidermal component, the lymphocytic infiltrate adjacent to the in situ portion was greater in comparison to that found adjacent to the invasive portion.

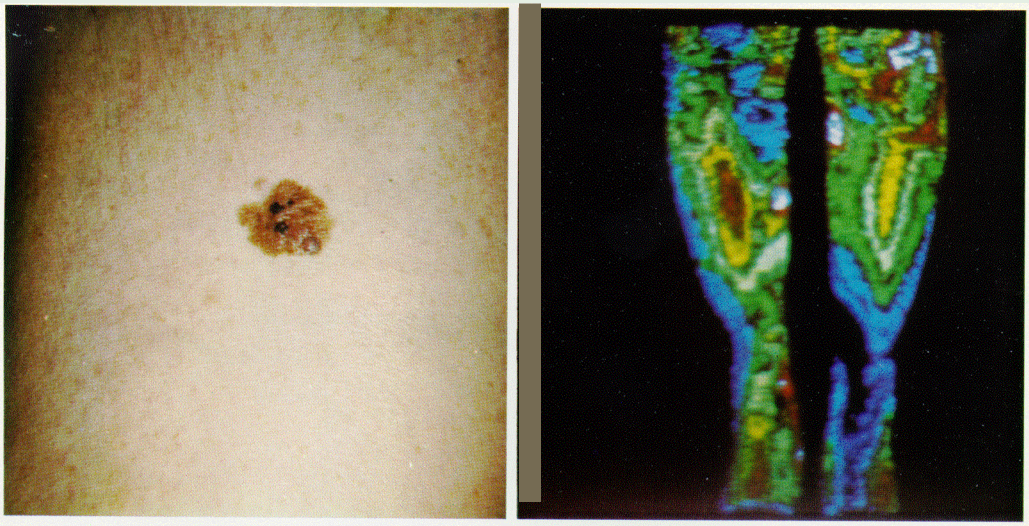
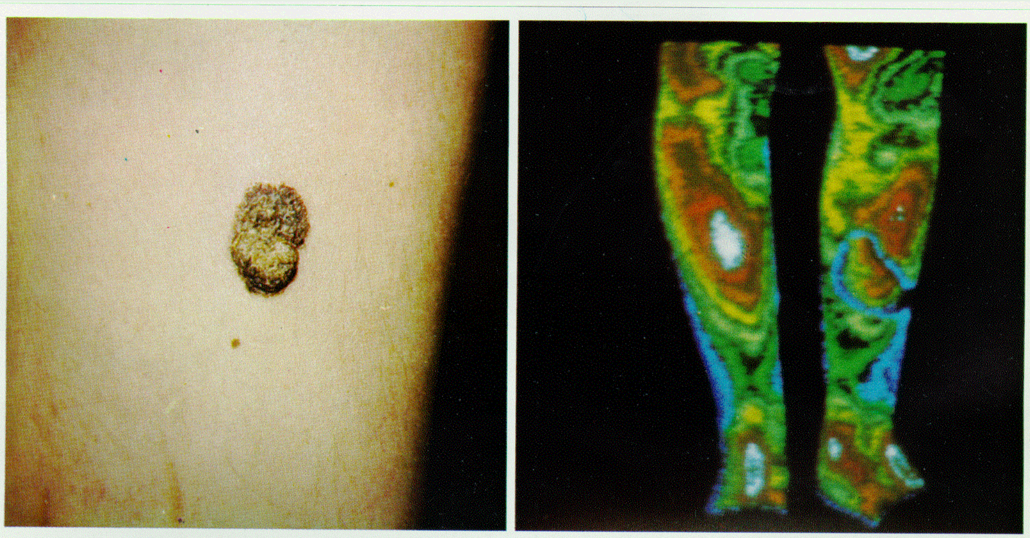


Fig. 4. Case 28. A) Right leg: nodular melanoma picked up at physical exam. The patient had a nevus from the time of birth and was without symptoms. B) Thermogram: the red area on the right leg shows a slight hyperthermia (+1°C).

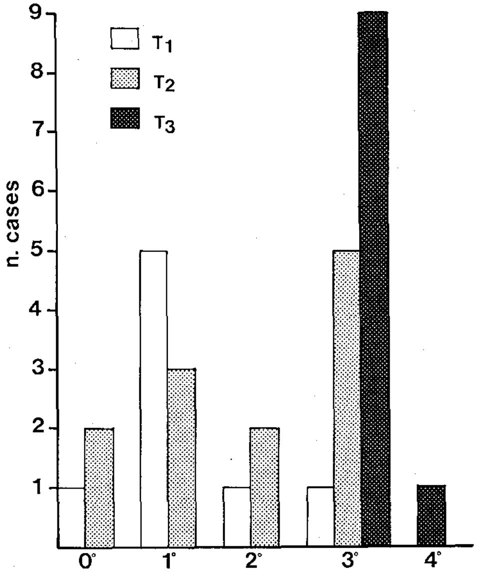


'Fig. 5. Case 20. A) Left leg: invesive melanoma with adjacent intra-epidermal component of superficial spreading type. B) Thermogram: comparision between the two limbs reveals paradoxical thermal differences despite the presence of the melanoma (« false negative »).

The most frequent cell type was the epithelioid (63,3%). Grade 1 mitotic activity had a slight, little significant prevalence over grade 3 (43,3% vs 33,3%). Neither cell type nor grade of mitotic activity appear to have any correlation with either the histogenetic type or the level of invasion.

At thermography 27 melanomas (90% of the cases) showed an increase in temperature. This was 3°C in 15 cases (55,5%), 1°C in 3 cases (29,6%), 2°C in 3 cases (1l,l%), and 4°C in 1 case (3,7%).

The correlations between the thermograms and certain data (overlying epidermis, TNM clinical stages, levels of invasion, and mitotic activity) are shown in graphs 1, **2,3,4.**



Graph. 2. Correlation between thermal gradient and clinical stage TNM.

Other data can be compared from table I, but appear to correlate less significantly.

Discussion

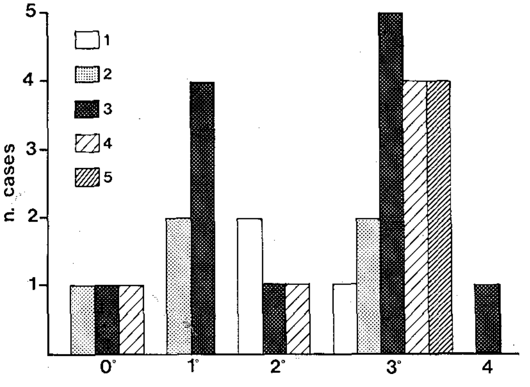
Thermography is a useful diagnostic method in the study of neoplasias, especially those of the breast, thyroid, and pigmented skin.

Primary cutaneous malignant melanomas are the most frequent exothermic tumors ([1,2,6,8,16,17]).

Eighty per cent of them are « warm », in contrast to pigmented nevi which are 80 to 90% «cool».

Thermograms can hint at the nature, benign or malignant, of the pigmented neoplasia. According to some studies repeated thermograms can be used to evaluate the invasiveness of the Hutchinson's melanotic freckle.

In the present series, 90% of the malignant melanomas were warmer than the surrounding skin by amounts varying from 1" to 4°C. The remaining 10% were cool, were all localized on the legs, always presented a portion that invaded various levels, and never had lymphocytic infiltrates. These cool melanomas had an overlying epidermis that was usually associated with hyperkeratosis, and never ulcerated. Their symptomatology was short, they were found in a pre-existent nevus, and they were of different histogenetic types. Nevertheless, the low number of cool melanoma cases does not permit us to draw definitive conclusions that would explain the negativity of their thermograms.



Graph. 3. Correlation between thermal gradient and level of invasion (Clark et al.).

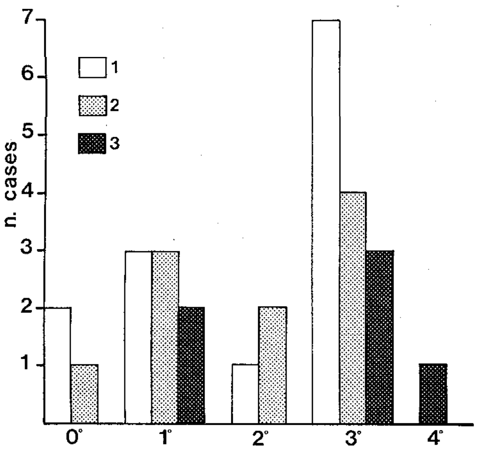
Comparing the degree of hyperthermia with the various clinical and histologic characteristics of melanomas, it, is evident that the increase in temperature of the neoplasia is not directly proportional to the level of invasion as measured according to Clark et al. ([3,4]) criteria; nor is it proportional to the mitotic activity.

Consequently the use of thermography to chart the invasiveness of the in situ types of melanoma, particularly the Hutchison's melanotic freckle, appears not to be supported by these data.

Moreover the thermal gradient of the neoplasia does not reveal its level of invasion; and it is this level which acts as the criteria in judging the correct size for surgical excision of the lesion or excision of the regional, usually anergic, lymph nodes ([15]).

Nevertheless all the neoplasias that invade to level 5 show a thermal gradient of 3” C.

The thermal gradient also appears to be



Graph. 4. Correlation between thermal gradient and mitotic activity.

unaffected by the age of the patient, or by the histogenetic pattern, the cellular type, or the site of the lesion.

Stage T3 represents the intense proliferative activity of the melanoma that results in lesions that are more than 5 cm. in size and/ or deeply invading the derma. This stage is always found in « hot » melanomas, those with a thermal gradient of 3” or 4°C.

The skin adjacent to a cool ulcerated area, in most cases, had high thermal gradients, usually 3°C. Consequently, it seems that the results of thermograms are greatly influenced by the overlying epidermis. In fact the negative thermograms were mostly associated with intense hyperkeratosis. A high thermal gradient in a pigmented neoplasia should lead to a diagnosis of malignancy without being pathonomonic of malignancy.

It appears to be directly proportional to the clinical grade of diffusion of the lesion. (TNM).

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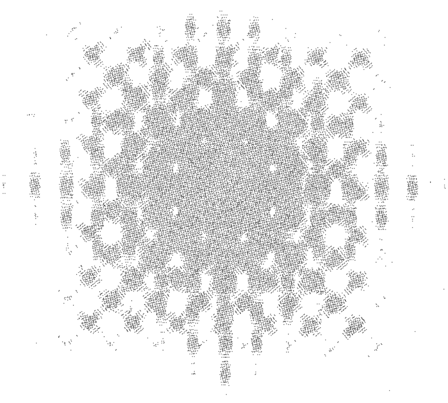

Thermographic follow up of medical treatment in extracerebral carotid insufficiency

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SUMMARY. Facial thermography can he used for three purposes. (1) Identification of vascular lesions in the extracranial carotid system. In 49 patients the thermographic false negatives were 9.1% and the thermographic false positives were 15.8%. Telethermography can thus he valid for screening before angiography. (2) Follow-up evaluation of medical treatment. (3) Appraisal of the efficacy of the drugs employed.

Key words: thermography; carotid insufficiency; medical treatment results.

A) Introduction

The object of this work is to examine the possibilities of employment, and the value of the information obtained, of facial telethermography (f.t.t.) in the study of cerebrovascular disease. F.t.t. can be usefully used to identify the haemodynamic alterations resulting from a cerebrovascular lesion, and to follow the developments of the lesion, both spontaneous and as a result of pharmacological and/or surgical treatment. F.t.t., absolutely bloodless, easy and quick to perform, has the advantage of possible repetition whenever the course of the illness requires it.

The normal facial telethermographic picture shows hair, eyebrows and eyes cold, end of nose and cheeks usually cold, forehead and perioral region warm. The thermic behaviour is pratically symmetric. There are no differences between the two parts of the face [2,5,6].

In the occlusion or serious stenosis of the internal carotid artery, the blood coming from the external carotid artery reaches once more the carotid syphon owing to the connections between ophtalmic artery, dorsal artery of the nose, infraorbital artery and supraorbital artery. The vascular supply of the frontal region depends on the frontal supraorbital artery, end-branch of the ophtalmic artery (Fig. 1). As the ophtalmic artery is used to send blood once more into the syphon, reduction or absence of the flow in the frontal supraorbital artery occurs, and this translates thermographically into a cold supraorbital triangular area.

The angiography (Fig. 2) shows the occlusion of the internal carotid at its origin and the hypertrophy of the facial and internal jaw arteries. Along the course of the infraorbital artery and of the dorsal artery of the nose, one can see perfectly the countercurrent flow once more into the ophtalmic artery as far as the syphon. The supraorbital artery is not visualized and this explains the hypothermia of the skin of this area. The superficial temporal artery is also hypertrophic in order to supply the vascular network of the fronto-supraorbital skin.

For thermographic purposes, temperature differences higher than 1°C are considered; lower thermal gradients have only been considered as a suspicious indication.

The frontal supraorbital (f.s.0.) region is the most important point of reference, but

Fig. 1. Outline of the vascularity of the supraorbital region. The dorsal artcry of the nose, the supraorbital artery and the frontal branch of the superficial temporal artery are evident.

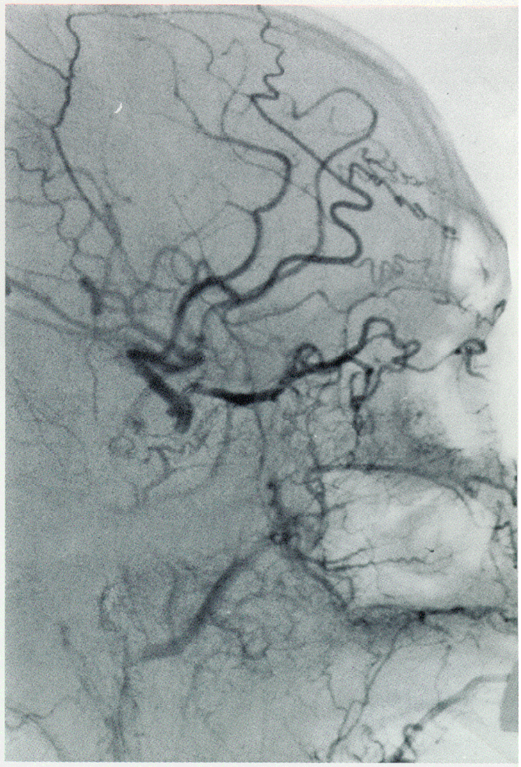


Fig. 2. Occlusion of the internal carotid artery; advanced angiographic phase (photographic subtraction). The ophtalmic artery is visualized rcceiving contrast medium countercurrently through the facial artery, the infraorbital artery and the frontal branches of the superficial temporal artcry. This pathway serves the syphon.

other regions have also been considered as they have a specific enough circulatory dependence [1, 2, 3, 4, 5, 6]. These latter are nose and fronto-temporal (f.t.) region. The nose is normally cold, but it becomes warm in conditions of increased flow along the dorsal artery of the nose. For the same reason, collateral perfusion in the superficial temporal artery can justify fronto-temporal hypothermia.

B) Material and method

The study sample is represented by 49 patients who suffered from acute cerebrovascular disease, hospitalized in the Neuro-

Tab. **1. Acute cerebrovascular diseases (49 cases).**

THERMOGRAPHY		*ARTERIOGRAPHY*
pathological (cold f.s.o. triangle)	*38* cases	stenosis/ occlusion carotid axis: 32 cases
		no stenosis/ occlusion carotid axis: 6 cases
normal	11 cases	stenosis/ occlusion carotid axis: 1 case
		no stenosis/ occlusion carotid axis: 10 cases

logy Division of the University Hospital of Verona.

As is summarized in Tab. I, a positive f.t.t., meaning a cold f.s.o. triangle, was found in 38 cases (77.5%), whereas in 11 cases (22.5%) there was normothermia without asymmetries.

In 38 patients who had a positive f.t.t., the arteriographic investigation showed 32 of them (84.2%) had stenotic or occlusive lesions of the internal extracranial carotid. Only in 6 cases (15.8%) were extracerebral vascular lesions not found. In fact, as the angigraphy proved, 4 were cases of diffused cerebrovascular lesions and 2 were cases of rupture of intracranial aneurysms. These thermographic « false positives » may depend on asymmetrical haemodynamic alterations in the territory of the ophtalmic artery that give pictures of hypothermia.

In 11 cases in which f.t.t. was pratically normal, angiography showed 10 cases with patent internal extracranial carotid artery and only 1 case of occlusion of it (« false negative » 9.1%).

The f.t.t. is also valid in the identification of stenotic and occlusive lesions of the internal extracranial carotid. In particular one can state that:

1. if the lesion is located in the main carotid artery, the thermography is usually negative;
2. if the lesion is located in the internal carotid artery, from the origin to the ophtalmic artery, the thermographic picture is almost always positive;
3. if the lesion is located in the post-ophtalmic tract, the picture is not constant;
4. if the lesions are bilateral the cold supra-orbital triangle is more evident on the side where the lesion is worse.
5. the threshold for thermographic detection is indicated by a reduction of calibre of the carotid by about 50% [5,6].

C) Results

Regarding the use of f.t.t. in controlling the effectiveness of pharmacological treatment of cerebrovascular lesions, personal experience is based on 24 patients trated with nicergoline *. The sample was divided into 4 groups, according to dosage and modalities of administration.

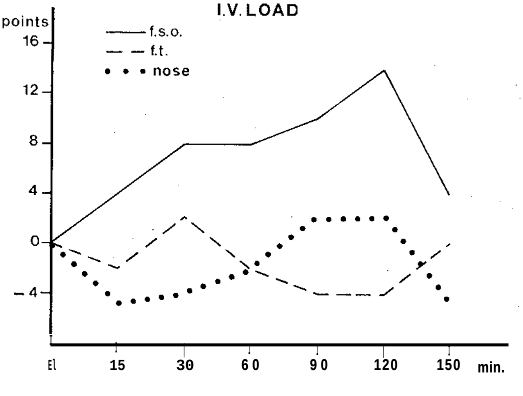
To be able to better appreciate the f.t.t. data, there was taken into account temperature variations also of 0.5°C. An arbitrary score of ± 10 points for a variation of ±0.5°C was chosen.

The drug was well tolerated and did not produce undesirable side-effects apart from the patients of the first group who suffered from a sensation of. diffused heat and sometimes reddening of the face. A slight reduction of arterial pressure was noted and this, in this kind of pathology, is to be considered favourably.

1. The first group, 5 patients, was given a 0.1 mg per kilo of weight dose of nicergoline, divided in two half-doses: the first half directly injected i.v. in l'-2', the second half in a perfusion i.v. of saline. The duration of the perfusion was, on average, 50'-60'. The f.t.t. controls were performed 15', 30', 60', 90', 120', 150' after the introduction of the first dose.

   In Tab. II, the thermographic variations, in the three regions considered, for the first group of patients are represented. In the f.s.o. region the drug

Tab. II.

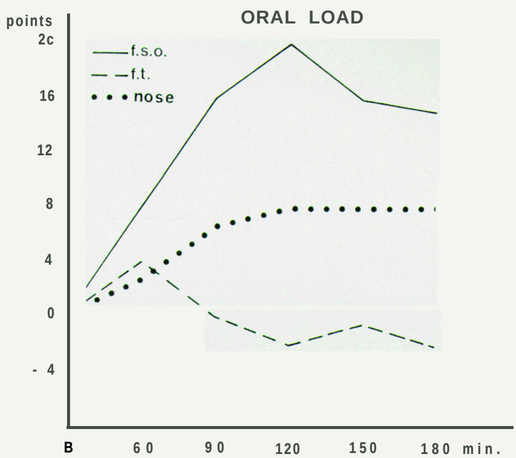


caused a heat increase in the cold triangle, that reached its highest point after 2 hours and then cooled down. The initial cooling of the nose indicates the reduction of the collateral flow in its dorsal artery no longer needed for the supplemental flow to the ophtalmic artery. The later heat increase of the nose probably is due to a diffuse hyperaemia. The f.t. region slowly cools as a consequence of the reduction of collateral flow through the superficial temporal artery.

2. The second group, 6 patients, was given a single oral 0.2 mg per kilo of weight dose. The f.t.t. controls were performed 60', 90', 120', 150', 180' after the administration of the drug.

The oral load (Tab. III) causes a heat

Tab. III.



increase of the cold f.s.o. triangle; it appears to be more continuous and consistent than in the patients submitted to the i.v. load. The later temperature fall, that the patients in the first group had, did not occur as quickly. The nose partecipates in this hyperthermia and tends to remain warm even when the f.s.o. region starts cooling. As the f.s.o. region warms up, the f.t. region becomes colder.

Fig. 3 represents the base-line thermogram of a patient affected by left extra-cerebral internal carotid artery occlusion, The left f.s.o. region is hypothermic, with a difference of temperature of -0.5°C, in comparison to the correspon-

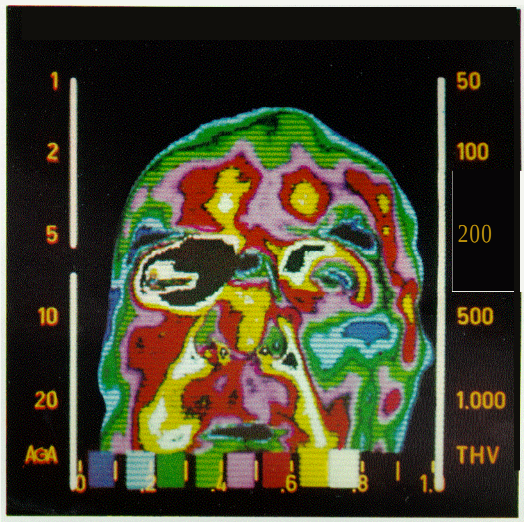


Fig. 3. Man, 67 years: occlusion of the left extra-cerebral internal artery. Base-line thermogram: cool triangle in left f.s.0. region.

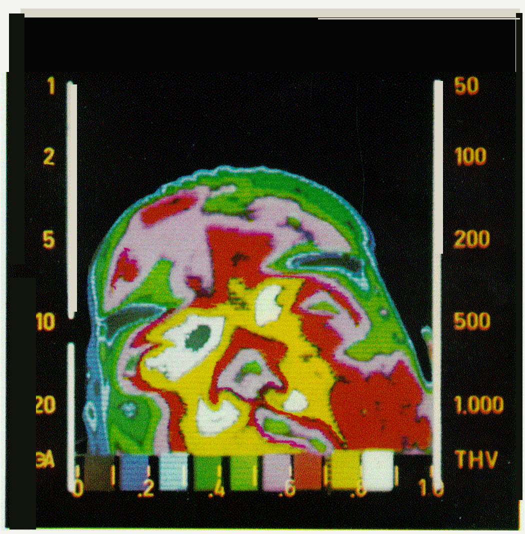


Fig. 4. Same patient as in preceding figure: 120' after oral administration of nicergoline (0.2 mg/kilo). Increase of the temperature of the left f.s.o. region and of the nose.

ding controlateral region. Fig. 4, 120' after the nicergoline oral load, shows a heat increase of the left f.s.0. region and the nose at the same side.

These results suggest some considerations:

a) the real effectiveness of the drug;

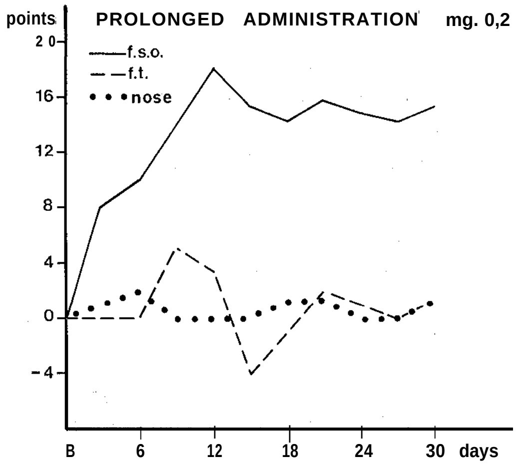
b) the oral administration has a better effect than the i.v. administration although one has to consider the different dosages of the drug;

c) the pharmacological effect is greatest between the first and the second hour, both for the i.v. and the oral load.

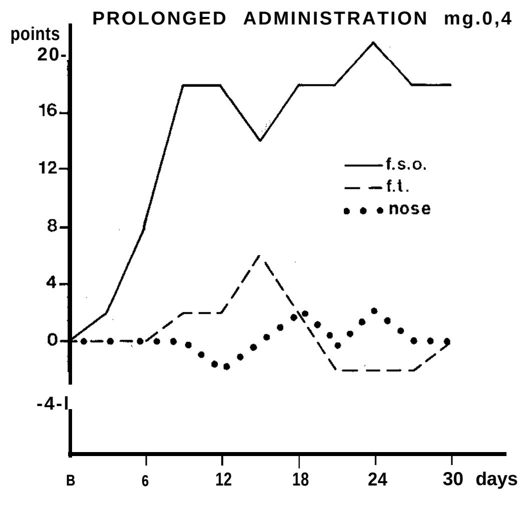
between the sixth and the twelfth days. The increase tends to remain constant during the treatment. The thermic patterns in the nasal and f.t. regions are little modified. This latter poor modification is very important because it means that the selective heat increase of the f.s.o. region does not depend on facial hyperaemia but, on the contrary, on an improvement of the flow in the internal carotid system and, consequently, the reduction of collateral flow in the ophtalmic artery.

Fig. 5 represents the base-line thermogram of a patient whose right f.s.o. region

Tab. IV.



Tab. V.



3. The third group, 7 patients, was submitted to a prolonged treatment by fractionated oral dose (3 times a day), up to a total of 0.2 mg/kilo of weight/day.
4. The fourth group, 6 patients, was submitted to a prolonged oral treatment, fractionated during the day (3-5 times a day), up to a total of 0.4 mg/kilo of weight/day.

The patients of these last two groups were submitted to f.t.t. controls every 3 days. The observation period lasted 30 days.

Tab. IV and Tab. V refer to the prolonged treatments. The f.s.o. region shows a heat increase that reaches its highest point

has a temperature lower by 2°C compared to the corresponding side; after 12 days of prolonged treatment with nicergoline (Fig. 6) an increase of 1°C in this area can be noted, whereas no significant modification in the other regions can be found.

In conclusion, f.t.t. is useful to identify a stenotic or occlusive lesion in the extracranial internal carotid artery. The validity of this method is high (84.2%) and also there are few false positives. F.t.t. can therefore be used as a screening before performing angiography-prior to surgical treatment. In patients that are to be submitted to medical treatment (and they are obviously

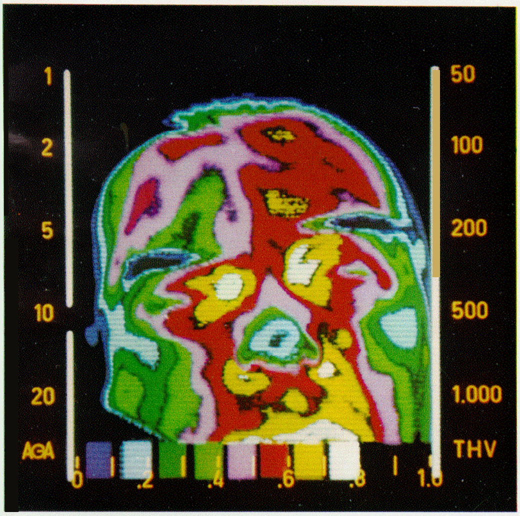


Fig. 5. Man. 63 years: occlusion of the right extra-cerebral internal carotid. Basc-line thermogram: cool triangle in right f.s.o. region.

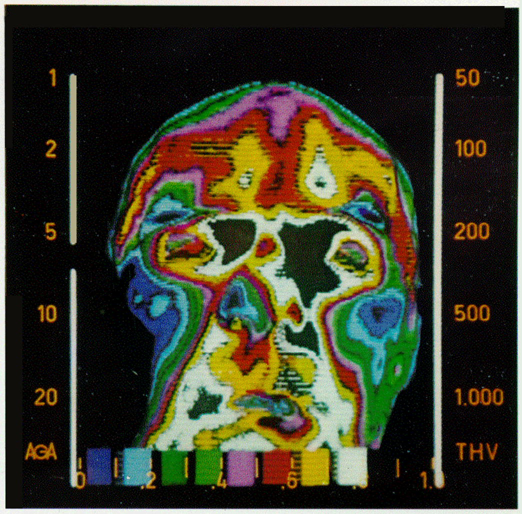


Fig. 6. Same patient as in preceding figure: 12 days after prolonged treatment with 0.4 mg/kilo/ day. Increase of' the temperature of the cool area is evident.

the majority) f.t.t. allows evaluation of the results of the treatment and testing the effectiveness of the drugs.

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Thermography in the hand angiopathy from vibrating tools

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SUMMARY. 25 workers with symptoms of vibrating tool angiopathy were examined with both thermography and photoplethismography. The thermal pattern of the normal hand was established. Thermography, even if done only under standard conditions, is capable of objectively demonstrating significant lesions in 84% of the cases. Photoplethismography of the same patients and under the same conditions is positive in only 24% of the cases. Thermography after a cold immersion test does not give substantially better results from those obtained under standard conditions. The usefulness of the method is advocated especially for disability insurance medicine and occupational medicine.

Key words: angiopathy; thermography; vibrating tools; chill test.

A) Introduction

Occupational lesions due to vibrating tools were noted in the first years of this century, a short time after the introduction of pneumatic perforators in the mining tunnel, and construction industries. Nowadays such lesions are more frequent because of the actual increase in the number of workers exposed and because of the increase in the number of cases that come to a physician's attention seeking to take advantage of the new insurance benefits offered them.

I) Vibrating tools

1. Vibrating tools are defined as those tools having high speed, low amplitude oscillating movements.

The *period* is the time necessary for the mobil point to return to its starting position.

Oscillation defines the movement carried out.

The physical variables of the tool, which influence the responce of the human organism to the vibrations, can be referred to:

a) the *frequency:* number of oscillations per second. The most dangerous frequencies are those that induce the phenomena of resonance in the whole human body or in part of it. In the hand-forearm-arm system, this phenomenon is produced in the band of frequencies between 30 and 80 Hz [1]. Hypothetically, depending on the characteristics of the vibrations there will be different pathologic patterns. Thus, low frequencies (10-30 Hz) should be responsible for bone and joint changes [2], and higher frequencies (up to 600 Hz) [3,4] should be more damaging to vessels and nerves. Recently it has been shown that the 125 Hz frequency band is the most suitable for causing vasospasms [5,6].

b) The *amplitude:* the distance travelled through by the mobile point during one oscillation.

When their frequencies are equal, the most dangerous vibrations are those with larger amplitudes [7].

c) The *acceleration:* expressed in meters per square-second. It is the only parameter perceived by the person exposed to vibrations. When the accelerations are equal, the vibratory sensation is better perceived with frequencies between 1 and 10 Hz [1].

2. Vibrating tools are classified according to the type of movement of the working part.

   a) Alternate (simple percussion: hammers, chissels, riveters).

   b) Rotating (simple rotation: drills, screw-drivers, millers).

   c) Mixed (alternate and rotating movement : pneumatic perforators).

3. Vibrating tools are used both in agriculture (power mouvers) and in industry (mining, construction, metallurgical and sheet metal, ship, building, aircraft, forest, textile, and shoe industries).

   Precise data are lacking, but probably more than 750.000 workers are exposed to the dangers of vibrating tools in Italy.

   In the U.S.A. there are more than 3.000.000 such workers [7].

II) EFFECTS OF VIBRATIONS ON THE HUMAN BODY

1. The effects of vibrations depend not only on the characteristics of the vibrations themselves (frequency, amplitude, and acceleration), but also on *other factors:*

   a) the weight of the tool (varying from a few kilograms to more than 30 kg.).

   b) the availability of a support.

   c) the type of handle the tool has'.

   d) the duration of exposure, and the duration of the interval between exposures [9].

   e) the characteristics of environment in which the tool is used (temperature, humidity).

   f) the possible means of protection.

   g) the more difficult to evaluate individual factors such as the variability of the build of the workers, their posture during work, and the amount of muscle contraction [9].

2. There are two groups of lesions produced in the human body by vibrating tools:

   a) The general reactions both physical and psychic, due to stimulation of various receptor organs and of other nerve structures (by the vibrations themselves, by noise, by environmental factors, and by the type of work). This group incluses the functional changes due to the stress reaction of the worker.

   b) The local and regional lesions caused directly by the vibrations. These are the most well known and involve the upper limbs. They include bone and joint, neurological, and vascular lesions.

III) LOCAL AND REGIONAL EFFECTS OF VIBRATIONS

1. Bone-joint syndrome:

   a) Clinically: pain, limitation of movement, and, in advance phases, snapping, and atrophy of the nearby muscles of the wrists, elbours, and shoulders.

   b) Radiologically: fine decalcification, epipheseal pseudocystic granular decalcification, especially in the semilunar bone and in the scaphoid; in advance phases the articular surfaces become deformed as in arthrosis, with intra-articular loose bodies, and reduction of the joint space [10,11,12,13]

2. Neurological involvement: it can be either central or peripheral [7,14].

   The most common pattern is a polyneuritis characterized by:

   a) slowing of the distal minimal conduction velocity,

   b) lowering of the amplitude of the potential measurable at the fingers,

   c) morphologic changes in the Meissner corpuscles biopsied from the skin of the thumb [15,16].

3. Vascular syndrome:

   a) clinically: Raynaud phenomenon in the fingers. This may appear bilaterally or may begin in one hand, the one that guides the too1 [9,17,18]. This syndrome consists of syncopal ischemic crises accompanied by paresthesia and even anesthesia, and limited motion of the fingers involved. The crises occur during chilling or during the use of vibrating tools. The evolution of this angiopathy is highly variable but depends principally on continues exposure to vibrations.

The pathogenesis of this angiopathy is uncertain:

1) inability of the vessels to catabolize substances that cause vasospasm and that perhaps form in workers exposed to vibrations [23],

2) the mechanical action of the 'callus formed during protracted use of such tools,

3) an immunological mechanism [25],

4) vascular spasm brought about by vibratory microtrauma with successive organic lesions of the arteriolar - arteriosclerotic type [19, 26].

b) Hemodynamic and arteriographic investigations have demonstrated a reduction in digital blood flow with frequent lesions of the vessel walls [19, 20].

On the basis of our experience and of the data from the literature, the frequencies of the lesions and their evolution can be outlined as in table I. For

Tab. I. Cronological evolution of the biologic effects of vibrations: the table shows the latency period for each effect., the peak of maximum frequency, and the maximum percentages of patients taken ill.

Effect	*Latency (months)*	*Peak (months)*	*%*
Psychic	0	< 1	100
Reflex physical	<12	12; 120	?
Bone-Joint	<24		?
Nervous	<24		10-30
Vascular	<12		10-90

the purposes of this work, the vascular lesions are more interesting because of their relatively early appearance, their relative incidence, and the fact that current investigative techniques are directed toward evaluating vascular involvement.

c) Instrumental tests (oscillographic, rheographic, photoplethysmographic, thermometric) demonstrate alterations sometimes under normal conditions, but more frequently during crises provoked by cold immersion [7, 21, 22].

The percent of persons affected by angiopathies varies in the literature: 10%, 30%, 50%, 90% [7]. Generally these' involvk nonhomogeneous sample groups, with variations in the type of tool and the duration of exposure. The instrumental tests commonly used to study vibrating tool angiopathies only serve to quantitize objectively the subjective symptoms of vascular damage that the patient complains of (paresthesia, limitation of movement, angiospastic crisis). Often the instrumental test results are scarce even with the artificial triggering of angiographic crises.

B) Aim of this research

The purpose of this work is:

a) to establish the diagnostic value of thermography for the identification of vascular lesions from vibrating tools.

b) to compare the validity of thermography to that of other investigative methods routinely used, usually photoplethismography.

I) MATERIALS AND METHODS

The patients were 25 men admitted to the Institute of Occupational Medicine. The median age was 5 1 years, with ± 5 standard deviations. All had worked in the mining industries. The median exposure had been 14 years, with ±3.9 standard deviations. The actual number of daily hours worked varied greatly, from 2 to 6. The tool used was always one of the various models of the pneumatic perforator with a weight of 22 to 28 kg., a teoretical frequency of 30 to 40 Hz, and an amplitude of 200 to 300 microns.

The case history was done with an orien-

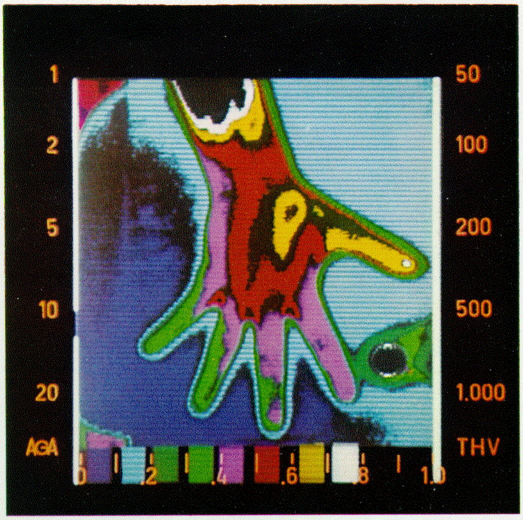


Fig. 1. Normal thermogram, standard conditions.

ted qucstionaire. Paresthesia in both hands was a complaint in 100% of the cases.

Angiospastic crises in both hands during cold exposure was a complaint in 88%.

The controls were 2.5 men with a median age of 45 years (ranging from 30 to 52). None had ever worked with vibrating tools nor ever had Raynaud's disease or Raynaud's phenomenon. Patients with previous traumatic lesions to the arms or shoulders were excluded from both groups.

There were 15 smokers in the cxperimental groups (60%), and 12 in the control group (48%). All these men were studied with both photoplethismography and thermography under standard conditions. Photoplethismography was done also after cold immersion (hands for 5 minutes in water at 5°C) in all patients; and thermography after cold immersion in 16 patients.

The thermographic standard conditions were: 20 minutes in a constant 18°C environment with thermograms of the dorsal surfaces of the hands.

II) THE THERMOGRAM OF THE NORMAL HAND

For an objective appraisal of thermographic patterns in vibration angiopathies the comparison with the normal hand thermogram is indispensable. The thcrmographic pattern of the hand (Fig. 1) in the control subjects was rather variable but nevertheless sufficiently classifiable (Table 11) considering three temperature gradients (hot, warm, and cool).

1 Carpal Region: three zones arc recognizable:

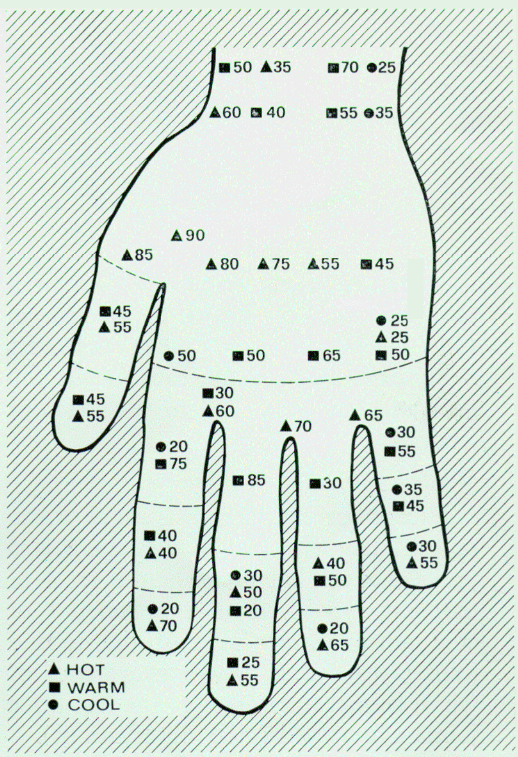
a) the ulnar side, where there arc mostly warm temperature areas (70%), sometimes cool area5 *(25%)*, and only once did there appear a hot area.

b) the *radial side usually* has hot or warm temperatures (85%).

c) the anatomic snuff box is the warmest region of the wrist, never being cool.

2 *Metacarpal Region:* always had hot or warm temperatures. t-lot areas decrease

Tab. I I. Normal thermal pattern. The number next to each symbol indicates the frequency in percent.



Tab. III. Data of the patients examined.

Patient	Age	Years of exposition	Clinical symptoms		Pkotoaletkismograpky		Thermography		
			Pare-stkesia	Raynaud's phenomenon	Standard conditions	After chill test	Standard conditions	LTG °C	Recovery time (minutes)
1) L.P.	55	10	+	+	normal	altered	altered	5	45
2) G.S.	43	8	+	+	normal	normal	altered	2	35
3) P.A.	56	10	+	+	altered	altered	altered	6	60
4) P.N.	55	9	+	-	normal	altered	altered	4	30
5) C.R.	39	8	+	-	altered	altered	altered	9	70
6) T.M.	47	12	+	+	normal	normal	altered	4	35
7) S.T.	50	10	+	+	normal	altered	altered	4	25
8) L.U.	50	12	+	+	altered	altered	normal	1	15
9) R.O.	48	10	+	+	normal	normal	altered	6	40
10) E.C.	52	20	+	+	normal	altered	altered	3	30
11) B.E.	54	19	+	-	normal	altered	altered	3	30
12) L.I.	55	19	+	+	normal	altered	altered	9	45
13) M.O.	59	19	+	+	altered	altered	normal	0,5	10
14) L.A.	45	13	+	+	altered	altered	altered	3	35
15) P.I.	52	15	+	+	normal	normal	normal	1	35
16) P.A:	58	17	+	+	normal	altered	altered	4	50
17) Z.U.	50	13	+	+	normal	altered	altered	3	-
18) R.I.	58	15	+	+	normal	altered	normal	1	-
19) B.E.	57	15	+	+	normal	normal	altered	3	-
20) E.F.	50	18	+	+	normal	altered	altered	5	-
21) F.C.	49	16	+	+	normal	altered	altered	6	-
22) E.G.	47	16	+	+	normal	altered	altered	5	-
23) G.G.	52	17	+	+	altered	altered	altered	4	-
24) L.P.	48	16	+	+	normal	altered	altered	3	-
25) G.L.	46	20	+	+	normal	altered	altered	4	-

from the first metacarpal (90% of the observations) to the fifth metacarpal (55%). Here there are linear cool areas along extensions of the axes of the fingers and corresponding to the extensor tendons.

3. *Metacarpal-phalangeal joints*

Except for the first, they have warm or cool temperature. In fact there is a prevalence of hot areas at the level of the first (85%), then a prevalence of cool areas at the level of the second joint (50%), and then a prevalence of warm temperature areas at the last three joints (50-65% of the observations).

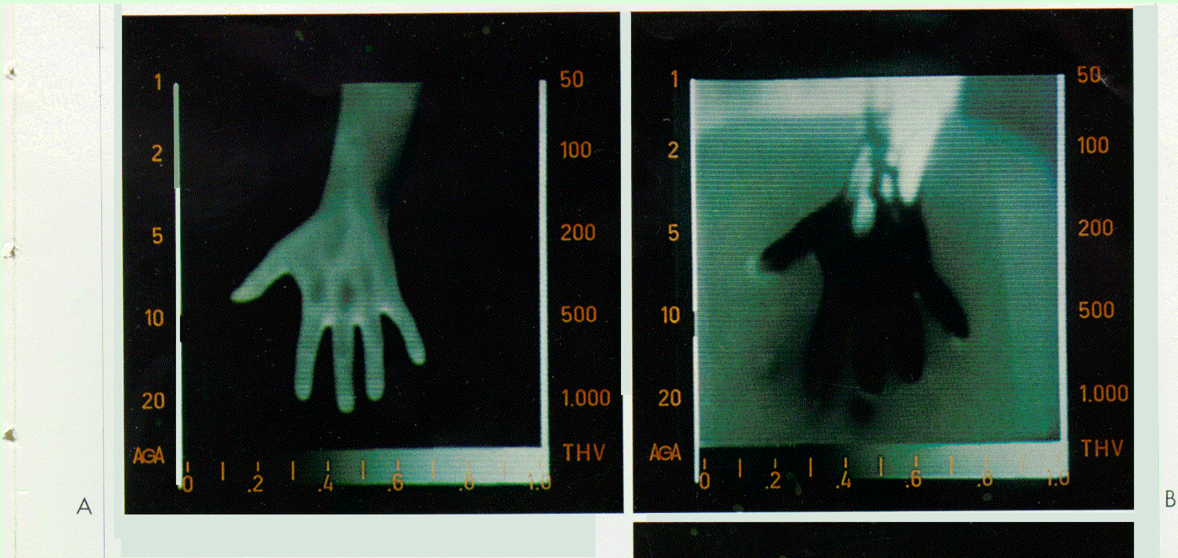
4. *Fingers*

Even in this sector the temperature diminishes from the radial side to the ulnar side. The thumb, in fact, is generally uniformly hot (55%) or warm (45%), while the fifth finger is cool (35%) or warm (45%).

The terminal phalanges are mostly hot. Cool areas were found in percentages varying between 20%, for the 2nd, 3rd, and 4th fingers, and 30% for the 5th finger.

5. *Longitudinal Thermal gradient*

It should be noted that, in each subject,



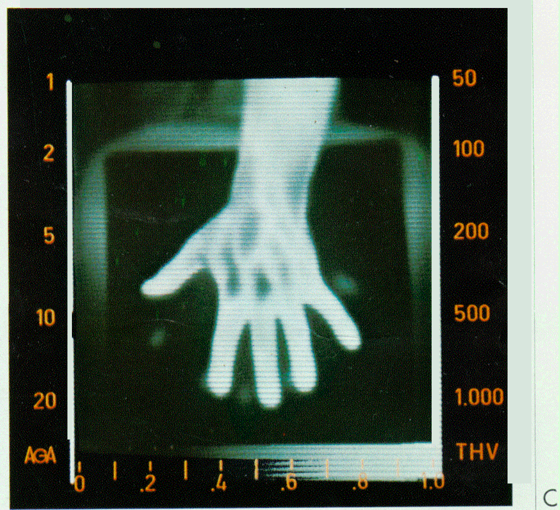


Fig. 2. A) Normal thermogram, standard conditions. B) Marked hypothermia 1 min. after chill test. C) Ten minutes after chill test, return to normal values.

the heat of the fingers does not correspond to that of the carpal and metacarpal. Therefore it is essential to refer to the Longitudinal Thermal Gradient (LTG), that is, to the difference in temperature between the carpo-metacarpal region and the fingers. In the normal hand the LTG values are always positive. That is, there is always reduction of the temperature from the carpo-metacarpal to the fingers. The LTG is highest for the first and second finger (1.2” and 1.9°C respectively), intermediate for the third and fourth (1° and 0.9°C), and least for the fifth (0.2°C). The law value of the LTG for the fifth finger is explained on the basis of the thermal situation of the ulnar side of the carpo-metacarpal region which, as been said above, is almost always cool.

6. Cold immersion test

After immersion of the hands for 5 minutes in cold water (5” C) the normal subject shows immediate marked hypothermia. This is more evident at the

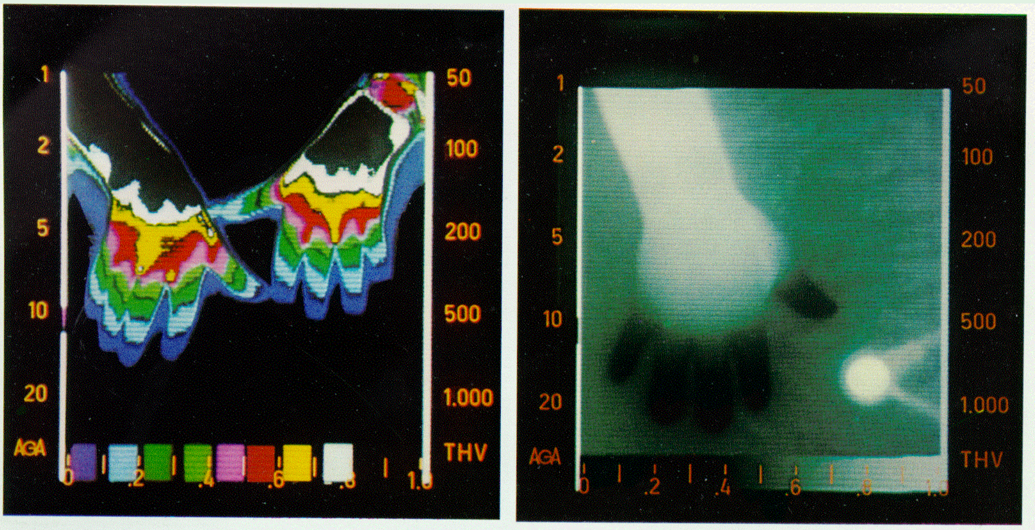


Fig. 3. Thermograms under standard conditions, in vibration syndrome: thermal amputation of all fingers bilateraly in two patients with Raynaud phenomenon.

level of the fingers, with an increase in the LTG to as much as 10-11°C (Fig. 2).

Thermograms done 15 minutes after the test show a constant return to the base-line thermal pattern.

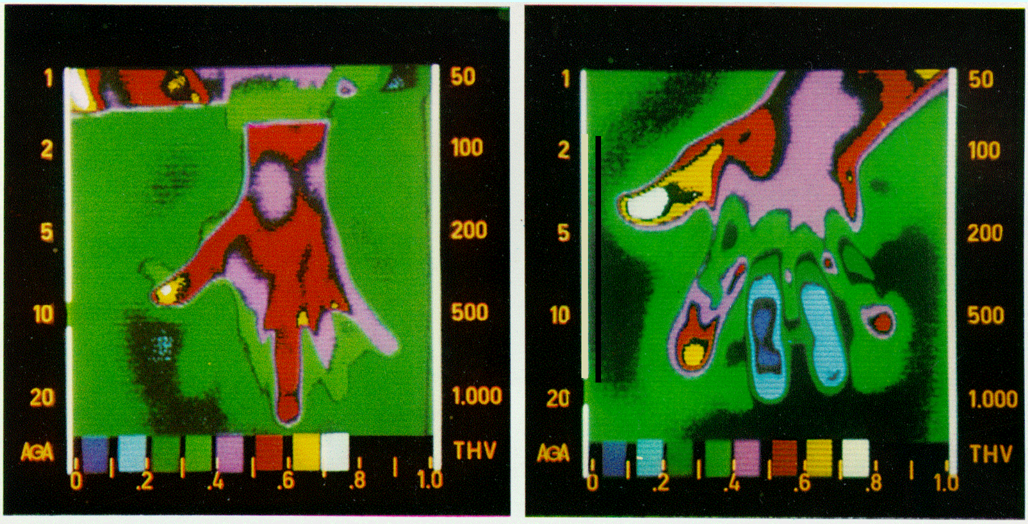
III) Thermographic Pathg Patterns in Vibrating toolTOOI. Angiopathies of the hand

The thermograms in vibrating tool angiopathy show more or less marked distal hypothermia with notable increase in the LTG. This is a pattern similar to that found in Raynaud's disease, either of the occupational disability type (workers exposed to vinyl chloride), or of the nonoccupational type [28]. Of the 25 patients studied thermographically under standard conditions (Table III) 21 cases (84%) had positive thermograms. In only 4 cases (16%) were the thermograms normal and none of these coincided with the 3 patients that had not complained of angiospastic crises in their case histories.

In 10 of the 21 positive cases (47.6%) the involvement was bilateral, with « thermal amputation » of all the fingers (Fig. 3). In the remaining 11 cases (52.4%) the lesion revealed thermographically was unilateral (7 righ-sided, and 4 left-sides). In 4 of these cases all the fingers of the involved hand were hypothermal. In the remaining 7 cases only one or two lingers were involved (Fig. 4), and these showed no predisposition for any of the five fingers. In the last group the first finger was never involved. The hypothermia is always more marked at the finger level rather than at the carpometacarpal level. This leads to a constant increase of the LTG's of the fingers involved, with median values reaching 4.5°C (with ±1.6 standard deviations), but always clearly above the normal values.

The photoplcthismographic exams done on the same patients, under standard conditions, gave clearly less satisfactory results (abnormal tracings 24%, normal tracings 76%) (Fig. 5). In only one case was the photoplethismogram abnormal when the thermogram was normal.

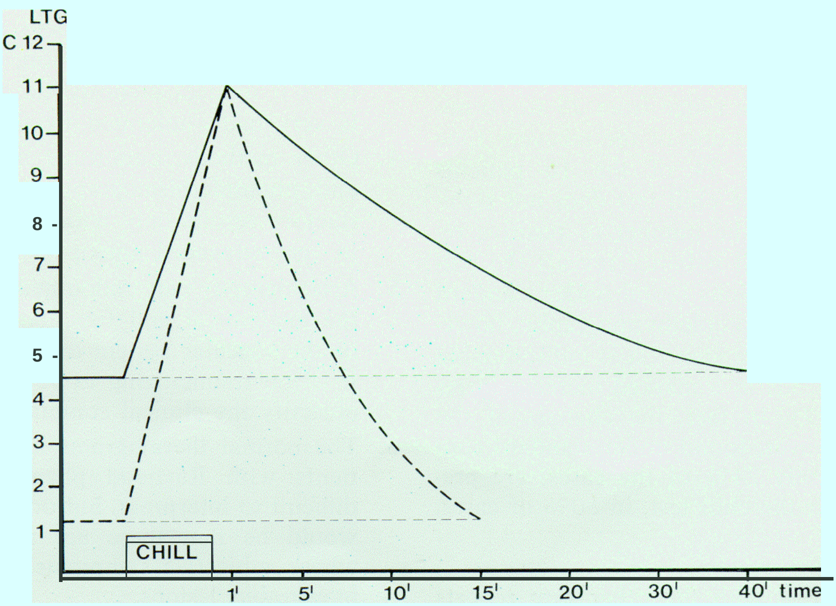
In 16 of the 25 angiopathy patients (13 with positive thermograms and 3 with negative thermograms under standard conditions) the *cold immersion* test was performed. The thermograms were taken every five minutes, from one minute after the chilling

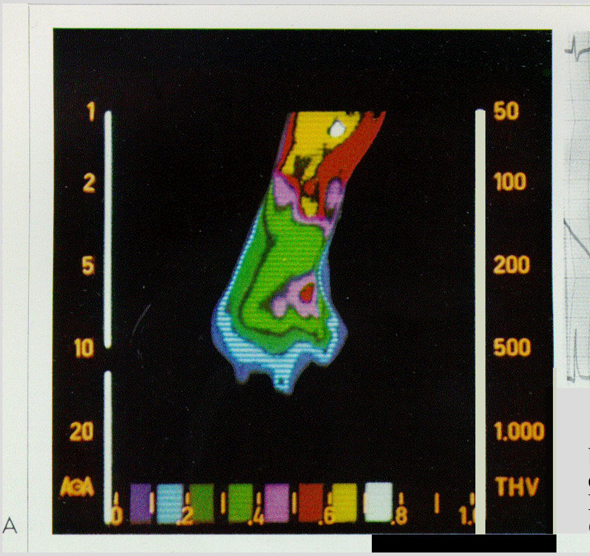


A B

Fig. 4. Thermograms under standard conditions in vibration syndrome. Two cases with localized lesions. A) Marked hypothermia of second and fourth finger left hand. B) Hypothermia of third and fourth finger left hand.

Tab. IV. The graph shows the LTG recovery times after chill test. Dotted line: normal subjects. Continuous line: patients with Raynaud phenomenon (vibration syndrome).





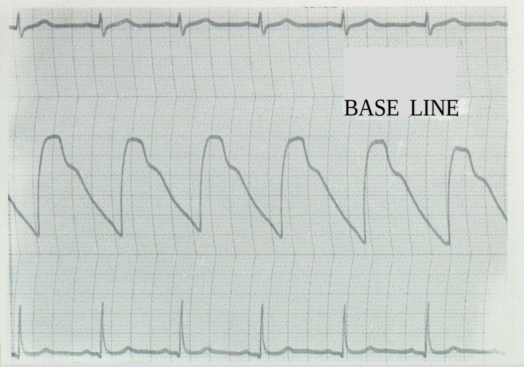


Fig. 5. Patient with Raynaud phenomenon, vibration syndrome. A) Thermogram, standard conditions. thermal amputation of all fingers. B) Photoplethismogram is normal under standard conditions.

until the values returned to their base-lines.

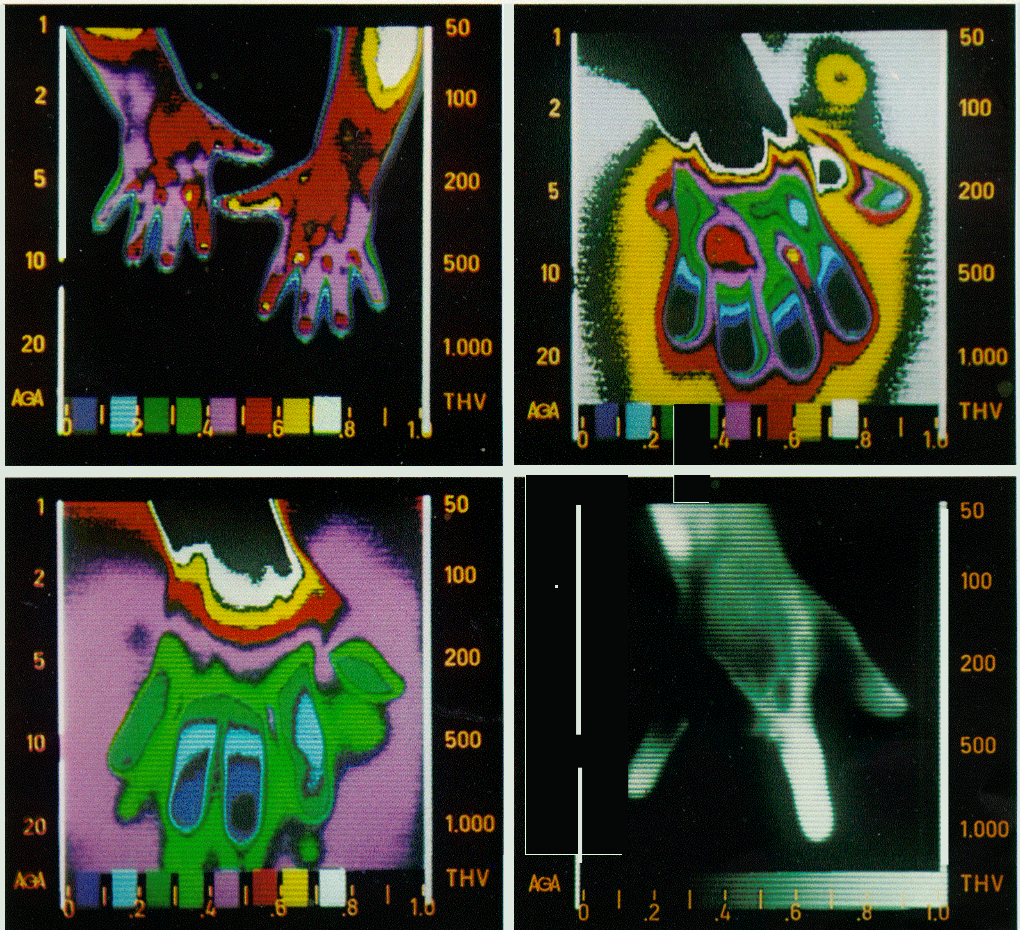
The chill test induces marked hypothermia in both the angiopathic patients and the normal subjects, with an increase in the LTG of about 6 or 7” C from the base-line values. (The one minute post-chill test thermograms had LTG’s as great a 11” C). In contrast with normal subjects, whose return to base-line values takes 15 minutes, the angiopathic patients have a very much slower return of their LTG’s to base-line values (Fig. 6). Their median time was 40 minutes (Table IV) with a range from 25 to 70 minutes. The lengthening of the recovery time was observed in 14 of the 16 patients (87.5%). Thus the chill test does not significantly increase the number of positive results, even though it better reveals the patterns of slight lesions found under standard conditions. In photoplethysmography, however, the cold immersion test is indispensable because it leads to a marked increase in results (Fig. 7). In fact, the changes of the sphygmic waves, found under standard conditions in only 24% of the cases, are presented, after the chill test, in 8O% of cases.

Conclusions

1. In contrast with the other rare reports in the literaturee [29, 30], this study shows that thermography is extremely useful in objectifying the subjective symptoms of vibrating tool angiopathy.
2. Thermography is very demonstrative even under standard conditions.
3. The scarce improvement in thermographic results after chill tests, in comparison to those under standard conditions (87.5% vs 84%), does not justify the use of cold immersion, especially since it induces angiospastic crises, and is very badly tolerated by the patients.
4. Other methods, cutaneous thermometry and photoplethismography, obtain satisfactory results only with a chill test or in very advanced angiopathy cases.
5. Arteriography can undoubtedly establish the anatomical and functional situation of the vascular system of the hand, but it is too traumatizing to be used just to objectify the clinical complaints.
6. The normal thermograms in certain patients with Raynaud phenomenon are difficult to interprete, but one hypothesis would be that these are initial stages where subjective symptoms precede demonstrable lesions.

A

B



C

D

Fig. 6. Patient with Raynaud phenomenon, vibration syndrome. A) Thermogram under standard conditions, slight hypothermia of 3rd finger right hand. B) Marked hypothermia of entire hand one minute after chill test. C) Extensive hypothermia persists after 20 minutes. D) Hypothermia persists in 3rd and 4th fingers, after 40 minutes.

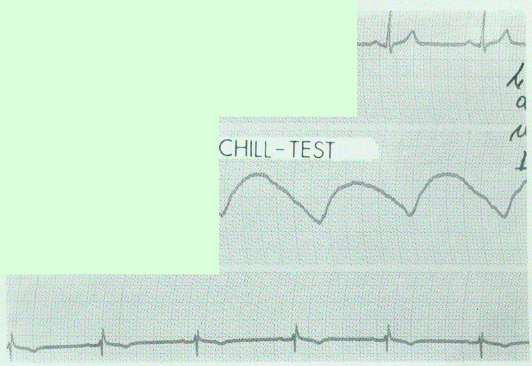


Fig. 7. Same case as Fig. 6: alteration of photoplethismogram after chill test. Under standard conditions the tracing was normal.

7. The suitability of thermography to innocuously reveals most of the vibrating tool angiopathies, makes it the diagnostic method of choice in lability insurance, occupational, and forensic medicine.

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The place of absolute temperatures in breast thermography

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SUMMARY. The absolute temperature map of breast thermograms remains static in 85.7% of normal women, when rescreened in the same hormonal phase. Absolute temperatures failed to be valuable in the differential diagnosis of breast lesions.

Key words: thermography; breast absolute temperature; breast temperature in menstrual status.

It has been recognised for a number of years that each woman has a characteristic breast thermogram, the pattern of which remains constant unless her hormonal status changes and which reverts to normal after any temporary change in that state ([1,2]). With the possibility of computerised thermographic screening, it would be useful to know if breasts have a static temperature map as well as vascular pattern. The equipment used in the project was an Aga 665 with a standard temperature reference source. There is an 11" lens used at a focal distance of 6 feet. The equipment is allowed to stabilise for fifteen minutes after switching on. The women cool for fifteen minutes and the screening is done in the same ambient temperature of 18" C plus or minus 1" C. Considerable care is taken to maintain these standards so that conditions for examination are completely reproducible.

The temperatures recorded are that of the areola, and the maximum and minimum temperatures, i.e. the range of temperature over the breast. The temperature of the supra-sternal notch is also noted. With the available equipment, it was not possible to assess the mean temperature or the total heat output, both of which I consider should be investigated.

Women were chosen for this project when they had normal thermograms by accepted criteria ([3]), and when their breasts were clinically and radiologically normal on two examinations at an interval of one year. Women with a past history of breast pathology were excluded. To avoid any effect of circadian rhythm, repeat examinations were done within the same hour of the day as the first examination. 758 women who fulfilled these conditions have been examined. The group consists mainly of childless women, those of low parity and those with a family history of breast cancer.

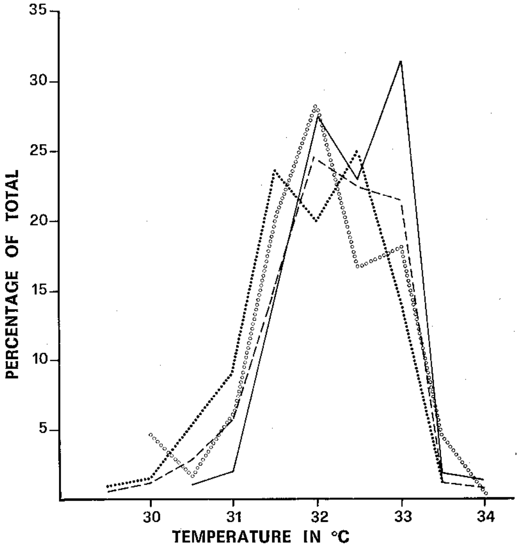
When re-screened after twelve months: 84.9% (642) had temperatures within 1" C of the previous recordings. Graph 1 shows the maximum temperatures of the breasts in those women, divided into three groups - those in the reproductive phase of life, the menopausal, and the post-menopausal. It will be noted that, on the whole, there is a general tendency for the temperatures to be lower in the post-menopausal group compared to the reproductive group. This is also the case with the areolar temperatures (Graph 2).

One hundred and sixteen women had changes over 1" C in two or three of the recorded temperatures (Table I). 28.2% of

Table I. **Constancy of temperature on rescreening.**

Temperatures assessed: maximum, minimum and areolar

Total number of women			758
Temperatures within 1°C of previous readings when rescreened after twelve months		642 (84.7%)	
Change of more than 1°C in two or three readings after twelve months		116 (15.3%)	
Of these 116 women			
Reproductive phase (35% down, 65% up)	33 (28.2%)		
Menopausal phase (49% down, 51% up)	31 (27.4%)		
Postmenopausal phase (88.5% down, 11.5% up)	52 (44.4%)		



Graph 1. Maximum temperatures in breasts.
— — — — 758 Normal controls;
———— 352 Reproductive phase of life;
o o o o 134 Menopausal;
• • • • 272 Post-menopausal.

these women had a regular menstrual cycle, 27.4% were menopausal and 44.4% post-menopausal. Of those in the first group, 35% had a fall in temperature and 65% a rise in temperature. The change in temperature in 80% of this group was considered to be due to hormonal influences. The alteration in temperature was recorded at a different stage of the cycle from the previous estimation and when repeated at the same stage of the cycle, was comparable with the original recording.

In the menopausal group of 31, 49% showed a fall, **51%** a rise in temperature and this varied from time to time - probably due to an unstable hormonal effect.

Of the 52 in the post-menopausal group, all but 6 had a fall in temperature. This could be important, in that a rise in temperature in a post-menopausal woman might herald pathological change.

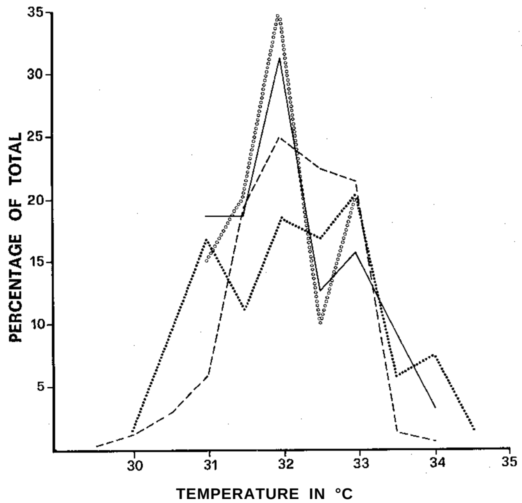
Table II. **Temperature ranges (in degrees centigrade) according to menstrual status.**

	Reproductive Phase			*Menopausal Phase*			*Post-menopausal Phase*		
	No.	*Max. temp.*	*Areolar temp.*	*No.*	*Max. temp.*	*Areolar temp.*	*No.*	*Max. temp.*	*Areolar temp.*
Controls (758)	352	30.5-34	28-33	134	30-34	2832.5	272	29.5-33.5	27.5-32.5
Cancers (54)	31	30-34.5	28-33	6	3 1.5-33	30-31	17	31-34	28-32.5
Pre-malignant (20)	12	31-33	27.5-31.5	5	31.5-33	29.531	3	32-33	30-3 1
Benign (32)	17	31-34	28-32	2	32.5-33	30.531	13	31-33	27.5-32.5

This project suggests that provided the screening is done in the same hormonal state, absolute temperatures should remain within plus or minus 1” C in 85.6% of normal women.

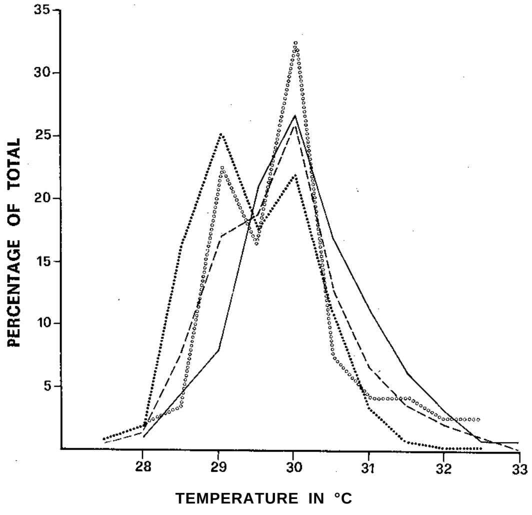
Encouraged by these findings, comparison of the temperatures in normal controls was made with those in the pathological breast of 106 women subjected to biopsy. It has been shown previously [3, 4] that thermography, using relative temperatures, has no part to play in the differential diagnosis of breast conditions but purely indicates the breast requiring further investigation by mammography. It was hoped that absolute temperatures would give a lead in the differential diagnosis of abnormal thermograms.

In the control women, the maximum temperatures (Graph 1) occur between 29.5°C and 34” C and the areolar temperatures (Graph 2) occur between 27.5” C and 33°C. In the cancerous breasts, the maximum temperatures (Graph 3) vary from 30°C to 34.5” C and the areolar temperatures (Graph 4) from 28°C to 33°C: Breasts with pre-malignant and benign lesions also failed to show any significant trend in maximum or areolar temperatures. The minimum temperature range was also similar



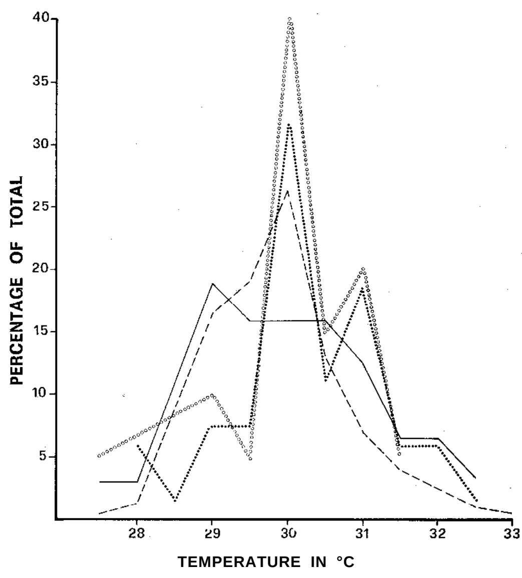
Graph 3. Maximum temperatures in breasts.

— — — — — 753 Normal controls:
106 Biopsy patients: . . . . . 54 Cancer;
0 0 0 0 20 Pre-malignant;
———— 32 Benign.



Graph 2. Areolar temperatures in breasts.

- - - - 758 Normal controls:
———— 352 Reproductive phase of life;
o o o o 134 Menopausal:
. . . . . 272 Post-menopausal.



Graph 4. Areolar temperature in breasts.

- - - -- 758 Normal controls:
106 Biopsy patients: . . . . . 54 Cancer;
0 0 0 0 20 Pre-malignant;
———— 32 Benign.

in all groups. Table II shows a comparison of the temperature ranges according to the menstrual status of the women. It would appear from this project that absolute temperatures are of no value in differential diagnosis of abnormal thermograms and have little place in breast thermography - as Wallace et al said in 1969 ([5]).

This is a preliminary report. The numbers are small and more work must be done in this field which should be easier with a digital print-out of absolute temperatures and computerisation to give mean temperatures and total head output. There may not. in fact, be an increase in total heat output in an abnormal thermogram but only a change in distribution. Temperature changes along the circadian and hormonal scales may be important and further investigation of these biological rhythms and how, if at all, they are affected by a cancer is required.

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The significance of an abnormal breast thermogram

by A.M. STARK, M.D., M.R.C.O.G.

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SUMMARY. While thermography will not indicate all cancers and should not be used as an isolated method of screening, it has a very definite place as one of the modalities in a screening programme and when used with a clinical examination, the false positive rates and false negative rates are considerably reduced.

Key words: thermography; abnormal breast; screening program.

One of the condemnations of breast thermography has been the high incidence of abnormal thermograms or « false » positives. This is fairly uniform throughout several published series (Table I), which is surprising when one considers that these series have been compiled with a variety of thermographic systems, used in varying conditions and with different standards.

'Table I. Percentage of abnormal thermograms.

Hitchcock et al. (1)	13.5%
Hoffman (2)	7.4%
Isard & Ostrum (3)	23%
Jones & Draper (4)	15%
Samuel (5)	13.8%
Stark	13.6%
Wallace & Dodd (6)	13.2%

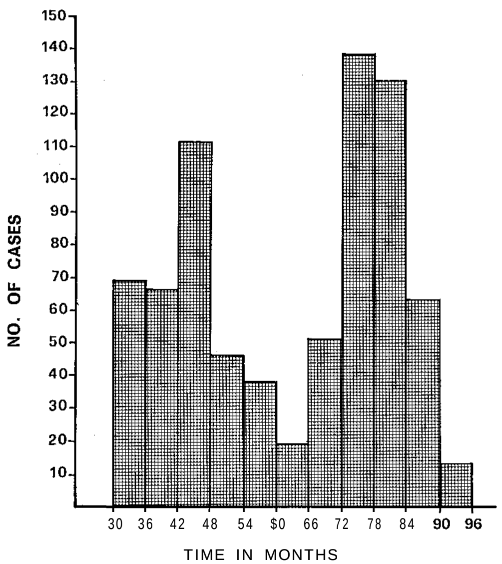
Throughout this work an Aga 665 Thermovision has been used, with in the past two years a standard temperature reference source. There is an **11"** lens used at a focal distance of 6 feet. The equipment is allowed to stabilise for fifteen minutes after switching on. The women cool for fifteen minutes and the screening is done in the same ambient temperature of 18" C plus or minus 1°C. Considerable care is taken to maintain these standards so that conditions for examination are completely reproducible.

The thermographic features considered to be abnormal are:

1) localised area of increased heat emission, a temperature differential of 1.5" C or more is significant;
2) localised increased vascularity with more numerous, tortuous, or dilated vessels;
3) unilateral increased heat of the areolar area. The fat layer, a good insulator, is absent at the areola and also there is a rich anastomosis of the superficial and deep venous systems in the Circle of Haller; and
4) generalised increase in temperature of one breast.

The essential factor is comparison of opposite parts, as well as an overall impression of the heat pattern using one breast as a control for the other.

In screening self-selected well women, 13.6% have been found to have an abnormal thermogram. A group of 744 women with abnormal thermograms have been followed for up to 96 months (Histogram 1). These were from a group of 746 consecutive abnormal thermograms. Two women in the group died of causes other than breast



Histogram 1. Duration of follow-up of women with abnormal thermograms.

cancer during the follow-up period at 36 and 52 months.

Of the 744 women, 57.7% were in the reproductive phase of life, 18.3% menopausal, 23.3 % postmenopausal and 0.6% postmenopausal but on hormone replacement therapy. A woman is considered to be menopausal when her menstrual cycle, previously regular, has become erratic and for two years following her last menstrual period.

The abnormal thermograms are more or less equally divided between right and left breasts - in fact 49 % to 5 1% . Before inclusion in the group, the thermographic screening was repeated at least once to confirm the abnormality - usually within two weeks.

Table **II. Percentage of abnormal thermograms with histologically proven cancer.**

Total abnormal thermograms	744
Carcinoma confirmed	91 (12.2%)
Carcinoma confirmed at later date *	44 (5.9%)
Total cancers	135 (18.1%)

* Three of these cases had become thermographically negative before radiological indications for biopsy.

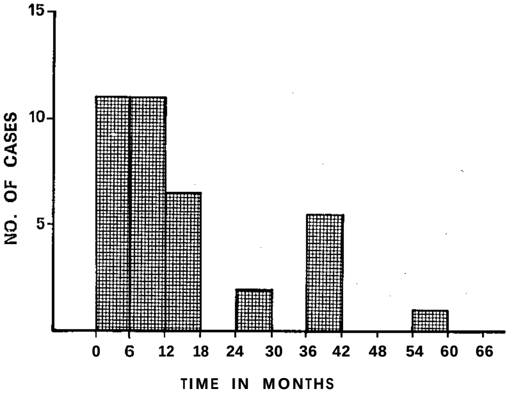
A total of 208 biopsies were performed at the time of the original abnormal thermograms, there also being an abnormal mammogram or clinical findings. The histology is as follows: 91 (12.2%) carcinoma, 56 (7.5%) severe epitheliosis, papillomatosis or very active adenosis, a picture considered by some pathologists to be pre-malignant, 57 (7.6%) benign lesions and 4 (0.5%) in which the histology was of normal tissue, even after considerable searching. This illustrates that thermography plays no part in the differential diagnosis of breast conditions.

A further 44 cancers were histologically proven in breasts with abnormal thermograms during follow-up. The time interval from first abnormal thermogram to radiological and/or clinical indication for biopsy varied from 3 to 58 months as shown in the Histogram 2. Before the biopsy was performed, the thermogram had become negative in 3 cases. These 44 cancers occurred in a group of 536 women with abnormal thermograms, i.e. the original group of 744 less the 208 women who had already had a biopsy. This is a pick-up rate for cancer of 82 per 1,000 which greatly exceeds the pick-up of 7.6 per 1,000 in my self-selected group as a whole, (7) and even the rate of 24.5 per 1,000 in my high risk group of well women (8). Of the total group of 744 women, the incidence of cancer was 181 per 1,000 (Table II). Although an abnormal thermogram is by no means specific for malignancy, any woman who has had an abnormal thermogram which can be reproduced at a second screening, must be considered to be at high risk of breast cancer.

Other causes of abnormal thermograms are as follows (Table III).

Clinical asymmetry

Clinical asymmetry in breasts such as size, previous biopsies which may result in a cold area over a scar or an area of warmth at the site of a deformity in the shape of a



Histogram 2. Time interval between first abnormal thermogram and clinical and/or radiological indication for biopsy-confirming cancer.

depression, scarring due to burns or obvious superficial veins in one breast were the cause of the abnormal thermogram in 83 women.

In the early stages of this investigation, infra red photography was used to demonstrate the superficial venous pattern. Very quickly I found that any veins shown by infra red photography were clinically visible on examination of the woman and the photography was discontinued.

This group of 83 makes nonsence of the attempt to evaluate breast thermograms in isolation from clinical facts. I firmly believe that a thermogram should be reviewed in the presence of the woman and that a clinical examination should be done immediately after the thermographic examination.

Hormonal effects

Hormonal effects were considered to be the cause of the abnormality in 142 women.

In a small group of 33 women, the thermograms were difficult to interpret if the examination was done late in the menstrual cycle - due to engorgement of veins. When repeated between the 7-10th day of the next cycle, the thermograms were negative, only to become equivocal again later in the cycle. It was noted that although their 7-10th day base line remained constant, the pre-menstrual picture could change from month to month. The contraceptive pill was not found to have any particular influence. The percentage of women taking such a hormone in this group was the same as in the total screened population.

Table III. **Other causes of abnormal thermograms.**

Total number (744 minus 252 biopsies)			492
1) Clinical asymmetry in breasts		83	
Size	8		
Obvious veins in one breast	62		
Previous biopsies	11		
Scarring due to burns	2		
2) Hormonal effect		142	
Cyclical	33		
Menopausal	109		
3) Fibrocystic disease diagnosed clinically and confirmed radiologically (no biopsy)		144	
4) Other conditions		11	
Carcinoma in contralateral breast	6		
Leukaemia	1		
Hyperthyroidism	1		
Haemangioma	2		
T.B. Sinus	1		
5) No cause found	112		

Table IV. **Influence of thermogram on final diagnosis in women submitted to biopsy in absence of clinical indications.**

	Total	*Hist. proven cancer*	*Pre-malignant lesion*	*Benign lesion*	*Negative biopsy*
Thermogram positive Mammogram positive	108	70 (64.8%)	30 (27.8%)	7 (4.9%)	1 (0.5%)
Thermogram negative Mammogram positive	40	16 (40%)	1 **(2.5%)**	21 (52.5%)	2 (5%)

The thermograms of menopausal women can also be difficult. If a base line is established during her reproductive life, it is frequently noted during the menopause that one breast has become less vascular - so causing asymmetry. The difficulty arises when such a women is first examined in the menopausal phase and asymmetry is noted. This must be classed as abnormal and the woman considered to be at risk. In 109 women in my follow-up, such a picture gradually became symmetrically avascular, or of equal vascularity to that of the less vascular breast at the time of initial examination, and so became* negative.

Fibrocystic disease

In 144 women, fibrocystic disease was diagnosed clinically and confirmed radiologically - but not by biopsy.

Other causes

Then there is a small group of miscellaneous conditions.

Six women had clinical cancers in the contra lateral breast. The remaining breast with its abnormal thermogram must be watched carefully. One woman had a very hot asymmetric axillary tail. This was the site of enlarged nodes due to leukaemia - previously undiagnosed. One hyperthyroid woman had an extremely vascular and mottled thermogram, impossible to interpret. After treatment of her thyroid condition this settled to a symmetrical thermogram of moderate vascularity. Haemangiomata were the cause in two women. One woman had a tuberculous sinus tracking upwards behind the breast. It had been discharging for six years when first seen by me. Over the next six years the sinus closed and her thermogram is now negative.

This leaves 112 women in whom no cause has been found for their abnormal thermogram - in my mind, the true false positives, i.e. 2.04% of total screened well women.

I have never recommended biopsy on the grounds of an abnormal thermogram alone - because of the multiplicity of reasons for abnormal thermograms and because there need not necessarily be spatial relationship between a lesion and the thermographic signs ([8]).

It must be accepted that all breast cancers will not give an abnormal thermogram. I have found that 21% of clinical cancers and 18.6% of pre clinical lesions have negative thermograms. For this reason, thermography must not be used in isolation as a method of screening but must be accompanied by a physical examination and preferably also a mammogram.

When used with mammography, thermography greatly increases the accuracy of screening for pre clinical cancer (Table IV). Of 40 women submitted to biopsy on the grounds of an abnormal mammogram alone, 40% were found to have cancer and 2.5% to have a possibly pre malignant lesion, but in 108 women with both an abnormal thermogram and mammogram, 64.8% had histologically proven cancer and 27.8% lesions of a pre malignant nature.

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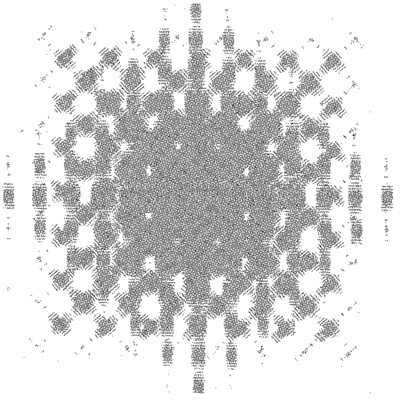

THERMOGRAPHY IN THE WORLD

This survey reports all information reaching the Editor about meetings with main or partial subject on thermographic applications. It is also disponsable to all thermographic Societies for printing meetings' abstracts.

*

❑ **ZARAGOZA (Spain).** The first International Course on Breast Thermography associated with the first International Course on Breast Xeroradiography was held from 22nd to 26th of March 1976 in Zaragoza.

The programme consisted of conferences, seminars and informal discussions. The two courses were directed by F. Solsona, Head of the Radiology and Nuclear Medicine Department, Ciudad Sanitaria « José Antonio ».

At the Course of Thermography the following reports were presented: *History of thermography* (F. Solsona); *Physical bases* (J. L. Santos-Capilla); *Technical* bases (L. Martinez-Comin); *Biological bases* (F. Solsona); *Clinical bases* (L. Martinez-Comin); *Tkermographic study* □↗ *the breast* (G. Madrid): *Thermograpkic breast unatomy* (L. Martinez-Comin); *Tkermographic patterns of the breast diseases* (F. Solsona); *Thermography of the breast benign tumours* (L. Martinez-Comin); *Thermography of the breast dysplasias* (M. Prats); *Thermography in the breast cancer* (N. J. Aarts); *Tkermogenetic power of tke breast cancer* (M. Gautherie); *Tkermographic classification and prognosis in the breast cancer* (J. M. Spitalier); *Tkermograpkic screening* □↗ *the breast cancer* (L. Rocchi); *Thermography and policy in the breast cancer* (J. M. Spitalier); *Thermography of the uterine cervix carcinoma* (G. F. Pistolesi); *Thermography in vibration diseases* (G. F. Pistolesi); *Xeroradiograpky and thermography in senology* (Ch. Gros).

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❑ **BATH (Great Britain).** The meeting of the Executive Committee and National Delegates of the European Thermographic Association was held in Bath from 8th to 10th of April 1976. On the same days, the E.A.T. Commissions on Terminology and Teaching, the Section on Industrial and Ecological Thermography and the Study Groups on Biothermometrology had their meetings. The Organiser of these meetings was E. F. J. Ring, from the Clinical Research of the Royal National Hospital for Rheumatic Diseases.

On the afternoon of 9'" of April, the Seminar on Thermography of Bone and Joint Diseases (Chairman: L.A. Bacon) was held. At this meeting the following reports were presented:

Historical introduction: rheumatology in Bath (J. A. Cosh);
Radiological, isotope and thermographic studies in rheumatoid arthritis (M. Johne);
Tkermograpkic evaluation of sacro-iliac joints (M. Sadovska-Wroblewska);
Tkermographic screening for scoliosis in adolescents (R. Woodrough, E. Cooke, M. F. Pitcher);

Calcitonin therapy in Paget's diseases of the tibia (E.F. J. Ring);
Evaluation of synovectomy in rheumatoid arthritis (I. Goldie);
The measurement of drug response in arthritis (P. Tiselius);
Anfi-inflammatory drug assessment by the tkermograpkic index (A. J. Collins).

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■ **NEW YORK (U.S.A.).** The Third International Symposium on Detection and Prevention of Cancer, sponsored by the International Study Group for the Detection and Prevention of Cancer (DePCa) was held from the 26th of April to the 1" of May at the American Hotel.

A Round Table was devoted to the Breast Cancer control-Mass Screening (Moderator: U. Veronesi) with a thermographic report presented by C. Valdagni. A workshop on Mammography, Thermography and Xerography (Chairman: P. Strax) was held at the same Symposium.

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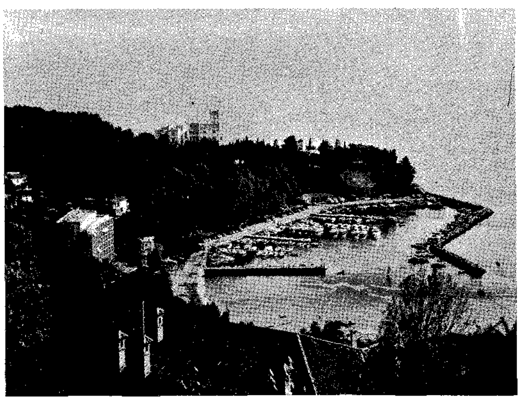
■ **TRIESTE (Italy).** The first International Congress of Italian Society of Thermography is held on 18th-19th of May 1976. President of the Congress is L. Fogher (via della Pietà 5, Trieste); Vice-Presidents: L. Campanacci, L. Dalla Palma;



The next First National Congress of Italian Thermographic Society will be held on 18th - 19"' of May, at the Adriatico Hotel in Grignano, a beautiful sea-village near Trieste. In the background, the Maximilian of Austria Castle.

General Secretary: G. Donaggio. The programme includes Round Tables, invited and proffered papers.

1st Round Table: *Thermographic screening of the breast cancer* (Chairman: C. Valdagni): B. Perani, M. Pietrojusti, L. Rocchi.

2nd Round Table: *Thermography in the* extra-mammary malignancy (Chairman: A. Toti): M. Cristofolini, L. Donati; G. Viganotti, L. Acciarri, A. Ghisolfi, N. Cellini, S. D. Bianchi.

3rd Round Table: *Tkermograpkic follow-up in oncology* (Chairman: A. Romanini): L. Carnaghi, N. Cellini, B. Perani, L. Rocchi, G. Viganotti.

Invited papers: *Thermography in oncological policy* (J. M. Spitalier); *The place of thermography in medicine* (M. E. J. Hackett).

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❑ **COPENHAGHEN (Denmark).** The 7th International Congress sponsored by the International College of Radiology in Oto-rhino-laryngology will be held from the 31st May to 2nd June 1976 (S. Brünner, President; P. E. Andersen, General Secretary).

A special session on Thermography in ORL is planned with an invited paper by A. Chiesa and L. Acciarri on *Thermography of the neck.*

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■ **ANCONA (Italy).** A meeting (organized by M. Lenzi) will be held on 11th-12th of June 1976 with 4 round tables devoted to senology.

1st Round Table. *Senology: clinical and organisatiorz problems* (Chairman: A. Toti);
2nd Round Table. *Breast and hormones* (Chairman: M. Lenzi);
3rd Round Table. *Mastopathies and cancer risk* (Chairman: G.F. Pistolesi);
4th Round Table. *Problems of breast diseases screening* (Chairman: M. Cappellini).

In each round table the problem of thermography related to different examination techniques will be treated.

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■ **TOKYO (Japan).** The 8th Annual meeting of Japan Society of Biomedical Thermography will be held on 19th-20th of June 1976. (Chairman: K. Atsumi, Institute of Medical Electronics, Faculty of Medicine, University of Tokyo - Hongo - Bunkyo-ku, Tokyo).

The programme consists of general papers, presented by K. Saijo (health screening and oriental medicine); J. Jto (radiology); Y. Miki and J. Munakata (dermatology and plastic surgery); Y. Nasu (industrial medicine): K. Yanagi (internal medicine); Y. Ohashi (tumours); R. Kanie (orthopedics); X. Yamasaki (surgery); H. Suda (obstetrics and hormones); Y. Sakurai (applied physiology); A. Nagasawa (oral-dental surgery); T. Togawa (deep temperature). In addition, the following special lectures will be presented:

N. J. M. Aarts: *The current status on medical thermography in Europe.*
M. G. Lapayowker: *The current status on medical thermography in U.S.A.*
Finally, an International Symposium on *Present status and future on biomedical thermography* will conclude the meeting.

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. **STRASBOURG (France).** The Symposium on « Non-cancerous Breast Diseases » (Ch. Gros, President, Louis Pasteur University; M. Gautherie, General Secretary) is programmed in Strasbourg from 30th of June to 3rd of July 1976.

Round Tables, invited papers and proffered papers are foreseen. Thermography fills a very important place in the Round Tables devoted to exploration methodology, to mastopathies and to cancer risk.

A' Pre-Symposium meeting is devoted, among other topics, to the post-graduate teaching in thermography and to the 5th Conference of the French Society of Clinical Telethermography; this meeting will be held on 28th-29th of June 1976.