ACTA THERMOGRAPHICA

Volume 1 Book 3

Content

LECTURE

The temperature of Europe

by M. GAUTHERIE

Department of Thermology, Louis Pasteur University, Strasbourg (France)

> « The brain may devise laws for the blood, but a hot temper leaps over a cold decree ». (Shakespeare, *The Merchant of Venice,* Act I, Scene 2)

« Heat is a central topic, the point where all roads meet. . . It is the hub of science, just as Greece was the hub of the world to the Ancients . . . ». This parody of famous words by Dastre the physiologist gets us right to the heart of our subject.

The scholar endeavours to separate the different aspects of a science so that he can better analyse them. But he must also reverse the process in order to fully appreciate the progress that has been achieved and to better coordinate and be more prepared for future progress. There should always be interchange between analysis and synthesis.

The present-day extreme specialisation that has followed in the wake of technology and technocracy has been beneficial in more ways than one. But the cosiness of exclusive specialisation dulls our natural adaptability.

The specialist must also be, or be complemented by what the contemporary North American humanist, Buckminster Fuller, calls a « comprehensivist » : a person who, whether naturally or by conscious effort, is always sufficiently detached to be able to view his science as a whole.

This approach is particularly suitable for Thermology. For this science of heat exists only a specific part of other studies and not as a separate subject in its own right. Yet heat is everywhere, and every science has its thermology branch: thermo-electricity, thermo-pathology, thermo-ecology.

It is paradoxical that all these branches are joined only nominally to the common trunk of thermology, which is nourished by the interrelated parameters of heat, temperature, and entropy and the four dimensions of space and time.

The recent development of thermology techniques, in particular those which produce images, and numerous acute problems which depend wholly or partially on thermology for their solution, such as cancer prognosis, biomass assessment or economy of energy, these all are reason enough to group together everything concerned with heat. Not only in the foundations of thermology, in inert matter, in human beings and in ecosystems, but also from the point of view of the exploitation of thermal phenomena for utilitarian purposes, especially in the fields of health, energy and food.

I invite you today, to reflect upon these ideas of cooperation, and I shall also attempt to justify some recent and probable future moves, made in particular by the European Thermographic Association and by the Louis Pasteur University in Strasbourg. I ask you in advance to excuse any excessive enthusiasm, and remind you that figuratively speaking, heat is the synonym of ardour, passion and zeal, and that, as Saint-Exupery wrote: « . . . *happiness and progress are only to be found in the warmth of our actions ».*

Heat everywhere . . ,

Compared with all other scientific terms, the word « heat » is very rich in meaning, especially in the figurative sense. The heat of the day, and of youth, of blood and of fever, the heated atmosphere of debates and auctions, the heat of battles or of victory, and also the heat of passion. It can be qualified by the most varied adjectives: heat can be mild and soothing, pleasant, and indiscreet, dry or humid, consuming and stifling.. . As La Bruyere said: . . . *de chaleur vient chaleu-*

Lecture given at the meetings of the European Thermographic Association in Bath (United Kingdom), on Friday 9th April, 1976.

reux, . . a wealth for our language. Man experienced sensations of heat and cold right from his beginnings, long before the era of fire, whereas it was only much later that he discovered, then defined the laws of electricity, magnetism and radiation . . .

It is not only in language that heat is everywhere. Even before birth we are enveloped in amniotic heat, and as Charles Marie Gros so neatly puts it: *Man, the eternal foetus, will always dream of his return to paradisiac heat.* We are surrounded by heat to such an extent, that we find it as natural as the air we pollute and the water we waste. In all systems, natural or artificial, biological or ecological, stable or evolving, heat and temperature play a most important role. Our daily life gives proof of it at every turn, and our wellbeing depends on the temperature of our bodies and of our environment.

It was taught physical thermology in an old Institute of Mineralogy, which I still remember fondly. There I studied the growth of crystals, from molten organic compounds and then from metals with low melting point, and through calorimetry and thermometry I acquired a feeling for the influence of temperature on the state and physical properties of bodies, and the absorption or release of latent heat during changes of state. As we know from everyday experience, heat penetrates everywhere, even more insidiously than air or water. Thermal radiation, conduction, and convection are vital phenomena, but difficult to master and control. The physicist knows how difficult it is to maintain an isothermal system, to measure an increase in heat, to register a temperature, particularly a surface temperature. Perhaps these problems could be solved more easily, if thermokinetics were taught in a more through and pragmatic way, and if the mathematical concepts of Stefan, Boltzmann, Fourrier, and Newton were considered more as a means than an end. The chemist is confronted with similar difficulties owing to the laws of Van't Hoff and Arrhenius, according to which the speed of chemical reactions, especially combustion, increases exponentially with the temperature. On the other hand, the two main principles of thermodynamics describe satisfactorily most physicochemical systems. The first one, formulated by Carnot, emphasises the confermation of energy for all systems. The second, formulated by Boltzmann, concentrates on irreversible processes and non-insulated systems. He points out that such a system evolves spontaneously towards a state of equilibrium, where molecular disorder is maximum. This disorder is measured by a quantity called entropy, which continues to increase during the evolution of the system owing to internal production and possibly to additional entropy from outside.

Likewise, temperature and heat flow are fundamental parameters in biology and physiology. At cell level, the enzyme systems, by which synthesis and metabolism are brought about, both in animals and plants, are only active between narrow temperature and pH limits. But although these two factors play parallel rôles, the thermal conditions of biochemical reactions are sometimes considered secondary, or even disregarded, often from university practical classes onwards. At organism level, heat production is the reflection of tissue activity, and it is significant that in man, thermogenesis is highest for grey matter and cardiac muscles. Blood, which distributes metabolic calories throughout different parts of the body, plays the rô1e of heat convector, just as important as its rô1e as conveyer of oxygen and water. The old concept of caloric in the sense of fluid which conveys heat retains its value in my eyes, and makes Claude Bernard's « milieu intérieur » one of the most brilliant expressions of Einstein's concepts of the non-dissociability and equivalence of matter and energy. Human beings are wonderful thermal machines, and the gap between the computer and the human brain is just as wide as that between the most advanced internal combustion engine and the thermoregulating mechanisms of homoeotherms. In the latter, thermoregulation has the job of maintaining homoestasis, indispensable to life and necessary for comfort; it is chemical in the heat generating organs, physiological in the vasomotor adjustment of circulation, physical at skin level, where heat changes take place due to contact with the atmosphere. Some habits, such as dress in Man, migration in birds, hibernation in some animals and the dormant period in insects, are no less regulating thermo-ethological reaction, sometimes only defensive or adaptable, but often vital.

As Odum stated, *« Temperature is the basic factor in ecology ». Night* to day and season *to* season changes in the environment are determined by rhythmic variations, inherent in the combined action of the sun's radiation and the movements of our planet. Land and water are characterised by a thermal stratification on which the distribution and growth of flora and fauna depend. In lakes and seas, for example, the water near the top, which is influenced by thermal fluctuations in the air, is warmer in summer and colder in winter than the water near the bottom, which is below the thermocline. Thus, in winter, some marketable fish migrate below the thermocline, because of their stenothermia, that is to say, their poor resistance to changes in temperature. On land, these phenomena are similar near the surface, but further down our knowledge is still speculative in spite of deep drilling and volcanic research. After descending 20,000 leagues under the sea and flying from the earth to the moon, Man whill have to undertake the journey to the centre of the earth. The temperature of the air is the most important climatic factor, and our almost daily complaints about bad weather and wrong meteorological forecasts, only go to show how complex thermoatmospheric phenomena are. The variety in vegetation, in living species, in ways of life, in economic activities from one part of the globe to another, is the direct result of geographical and seasonal variability in the thermosphere, as is shown by the study of natural and artificial microclimates. The effect of temperature on the phenotype and on fertility has been demonstrated in many organisms.

Boltzmann's principle of order describes the evolution of irreversible systems, involving short-range molecular interactions. But it doesn't apply to either the astronomic structures characterised by long-range forces of gravity, or to biological structures. The latter are, in fact, highly organised, both from the architectural point of view, in its macromolecular protein combinations, and from the functional point of view in the chains of metabolic reactions; also, they correspond to open systems, exchanging not only energy but also matter with the exterior. General thermodynamics, developed recently by Prigogine and Glansdorff open the way for conciliation between thermology in physics and in biology, starting from the concept of dissipative structure. Such structures are brought about as the results of a system's wide fluctuation from a thermodynamic equilibrium, and they are kept far from this equilibrium due to exchanges in energy and/or matter with the exterior. There are examples of spatial dissipative structures: in hydrodynamics, Bernard's instability corresponds to the formation of hexagonal macroscopic convection cells in a liquid heated to a high temperature; in chemistry, Zhabotinsky's reaction, in which the oxydation of malonic acid by potassium bromate in the presence of cerium ions, leads to the formation of a build-up of alternate layers composed of tri-and tetravalent cerium ions. The application of the concept of dissipative structure in the working of biological systems is just in its infancy. However, encouraging results have been achieved for the glycolysis cycle and cerebral waves, which can be described as temporal dissipative structures. More recently, Eigen's research has shown that the interactions between proteins and polynucleotides enable the system to reach a remarkably stable final condition, characterised by a genetic code. The concept of dissipative structure should also be applied to the ecosystems, which are open ones, characterised by exchanges in energy and matter with the exterior.

In this way, heat has clearly added a new dimension to various scientific disciplines. But in addition to all laboratory experiments, there is something more precious: human warmth. This source, from which comes friendship, is perhaps the most noble form of emotion, whereas the physical heat is generally the least noble form of energy. For example, the family circle or our close frieds, many a time, warm our hearts. It is something almost natural, born of kinship, of neighbourliness, of shared experiences and moments enjoyed together. What is in fact warmer than the smile or gestures of a small child, or reminiscing over hard times, or recalling warm memories, by the fireside? Does it not, however, restrict the range of our emotions and progress, to limit ourselves, consciously or not, to the ties of family or friendship which life provides us with? Shouldn't we reach beyond these friendships in order to further enrich our heart and mind, with all that might distinguish us from others?

In truth, such bonds are difficult to form outside our own frontiers. The reason lies no doubt in the linguistic, idealogical and socio-economic barriers, but more so in some defects in the school or parents' teaching of contemporary history. We are crammed with preconceived ideas, from all English girls having freckles, to all Germans being unfeeling, and we are convinced that the path leading to understanding with other nations is strewn with insurmountable obstacles. Luckily, young people take little notice of such cliches, and are able to cast them aside more quickly than ever before. The older generation should first recognise this quality of theirs. I well remember, that when I was in my teens, my first artistic and amorous experiences were, by chance, English and German. In the context of a rather individualistic and chauvinist education, these pleasures were a surprise. Since then, I make every effort to watch, listen and understand, regardless of time, place or nationality,. . . For each human being and each nation has its good points, not to say outstanding qualities. And these are easy to discover, by those who are not hampered by Aesop's beggar's bag, asking everyone what he is able to give. We just have to show good will and good humour, following the example of Major Thompson, who found France very Gallic but nice.. .!

Some will complain that this constant search for friendship is vain, naive, and even ridiculous. Regardless of that, let us grant them that it is a Folly, joining with Erasmus in the praise of this quality which is the source of all our real pleasures . . . *« Indeed, when one thinks that all men are condemned by nature to suffer some basic* neck and breast uncovered 10 to 12 minutes in a room at an ambient temperature of 18°C. Then pictures of the neck are taken with an Aga Thermovision Unit 680. It can be helpful to observe the rewarming after having cooled the neck with alcohol. But we do not use this procedure for every patient. Pictures are in black, grey, and white. The temperature scale usually chosen is 1 to 10°C; the temperatures are measured with an accuracy of 0,5°C. The nodule is slighty encircled on the skin with a dermographic pencil. On the thermogram a mark is taken either with a fine guide which indicates the nodule's center or with a metallic ring which is not in contact with the skin. If necessary, and in order to be more precise, a Polaroid photo of the neck is taken in the scanning position.

ANALYSIS OF THE CASES

The microscopic examination revealed 59 cancers out of 364 studied cases. In reality, for 7 of them, the malignancy did not seem certain to one of our histologists, who considered them as only potentially cancerous; we discarded these 7 cases. Consequently, the analysis concerns 52 malignant diseases. They are classified by the histopathologists as indicated in the Table I.

Tab. I.

	Number of cases
Papillary carcinoma	18
Follicular carcinoma	9
Mixed papillary and follicular carcinoma	9
Polymorph carcinoma	3
Sclerosing occult cancer	3
Trabecular carcinoma	2
Medullary carcinoma	3
Intrathyroid metastasis (hypernephroma) (bronchial epithelioma)	2
Anaplastic neoplasm	2

Table II summarizes clinical data according to age, sex and physical examination.

For 14 patients, the nodule appeared 3 to 6 weeks before examination. For the other cases the nodule discovered accidentally. 5 patients with a solitary nodule had regional lymph nodes; 11 out of 12 multinodular goitres were old and 4 had recently grown.

Tab. II.

		Number of cases
Age (years)	under 30	16
	30 to 50	17
	over 50	19
Sex	male	44
	female	8
Palpation.	isolated nodule	34
	2 or 3 separate nodules	6
	multinodular goiter	12

For the 12th case, the goitre developed after two operations, the first for toxic adenoma, the second for Graves disease.

Table III gives the results of the isotopic scanning.

Tab. III.

Palpation	*Radioisotopic scan*	*Number of cases*
Solitary nodule	Hypoactive area	27
	Heterogeneous area	4
	Normal	1
2 or 3 nodules	All hypoactive	7
	One hypoactive	1
Multinodular goiter	Overall hypoactive	3
	Heterogeneous	9

In two cases with only one nodule at the physical examination radioactive scanning showed two hypoactive areas. So we can count at least 20 cases of multiple nodules. Nevertheless histopathological controls revealed only one cancerous focus, out of 10.

Apart from multinodular masses, pathological associations were:

friendly one. And WC *realise that we are of the same world . . . ».* The fact that discussions are now taken for granted, is a big step forward, encouraging optimism. For European reality can only begin with a clash of mentalities and an exchange of ideas. Gradually the ordinary people and the young are forming friendships, thanks to *a* great increase in school, artistic, tourist and economic exchanges.

Scholars are certainly strongly convinced of this evolution, which they experience almost daily in their literature, instruments and travel. It may well be that scientific Europe can be more easily brought about than all the others, because scientific method teaches modesty, and because the research worker or lecturer realises that scientific progress can be the work of anyone, irrespective of Nationality. C.E.R.N., in Geneva, is the outstanding example of this: *its* success in corpuscular physics is the work of several countries, pooling their great financial and intelectual resources. Thd work of the European Science Foundation, recently installed in Strasbourg, should crystallize and reflect the notion of a European scientific community.

Many learned societies whose European purpose is written into their statute, get no further than their good intentions: Because establishing contacts and creating international research teams, demand more than just rules and skills. Scientific association only survive and prosper if their leaders can give them a soul and human warmth. These qualities are a guarantee of success, immunisation against the dangers that come from sheer size, breakaway groups and bureaucracy. The European Thermographic Association has been growing for more than five years, emboying this state of mind. All those who work for it have to struggle each day with their professional and personal worries. Much good would European Thermography do them, were it not also an opportunity to meet their friends. I wish, therefore, to pay hommage to my thermologist colleagues, who have accepted a rôle in furthering their discipline, in particular, to those present today. For they are men of good will.

But incidentally, in speaking of men, or of Man, to disegnate Humanity, or our work groups, we are involuntarily perpetuating the myth of machismo, the deification of the male. Is this not untoward, at a time when 1975, Women's Year, has just drawn to a close! Is it not even ungracious towards mothers, wives, girl friend and daughters, who are the catalysts if not the leaven of all our joys and actions? Well, for our female colleagues who have already helped to give birth to and nourish thermology, I would like to quote a few lines from Holderlin, entreating Vulcan:

« . . . spirit of the familiar fire,. to come and wrap woman's tender heart in the clouds, to come and protect these flowers of infinite peace and kindness in the gold of *dreams. . . ».*

Heat is of service to Man in all his activities. It occupies a considerable place in daily domestic problems, from cooking and freezing to heating and air-conditioning. In industry, it is the invisible tool, causing multiple transformations, be it in refining oil, distilling alcohol, smelting, manufacturing steel and glass, moulding plastics, or preparing medicaments. Produced or exploited in internal combustion or jet engines, in gas or steam turbines, in nuclear fission reactors and breeders, heat is a factor in the propulsion of vehicles and supply of electricity. By the way, those who rise up in arms against the installation of nuclear power stations, are paradoxically less hostile to the atomic arms race, and they would probably be the last to give up their home comforts. All discussion on this serious problem demands great integrity of judgement and deep concern for Humanity, and it should exclude apocalyptical visions and political aberrations. With all these spectacular implications, we tend to forget that the heat of the sun makes the corn grow, ripens the grapes, and also makes us happy and exuberant without knowing why. The measurement of temperature and heat-flow enables the soldier to detect *a* camouflage and reach his target, the doctor to detect an illness and give a prognosis, the ecologist to catalogue the earth's resources and evaluate pollution, the farmer to get the best yield and create new species. It is very significant that the fourteen planning groups under France's « 7th Plan », are all more or less concerned with calorific energy and thermology techniques, particularly in health and welfare, energy and industry, agriculture and food.

Rises in temperature, whether rectal or cutaneous, reveal clearly a great number of illnesses. Fever and the association rubor-calor-dolor are the major pathological signs. Ever since Wunderlich's famous clinical experiments last century, the thermometer has been an essential instrument in medicine, assisting hand and eye, just as the stethoscope and sphygmomanometer. Cutaneous thermography, either infra-red or to a lesser degree by liquid crystals, is at present useful in the diagnosis of numerous mammary, vascular and particularly rheumatic diseases; above all it supplies conclusive information for the prognosis and therapy in breast and skin cancer, due to the connection between heat and the development of cancerous tissue. Thermotherapy exploits the beneficial effects of heat on skin, pain, and blood circulation, and all kinds of methods are used, some centuries old. Localised heating of tissue can be carried out with short waves or fango mud baths, or total heating of the body with baths or saunas. In the treatment of cancer, attempts have been made to potentialise the effect of ionising radiation, by creating a selective hyperthermia in the tumour, or to set in motion a kind of selective self-destruction of the malignant tissue by inducing a general hyperthermia by immersion near the lethal temperature.

Even in our modern world, where aesthetics and fashion play such an important part, clothes and dwelling places have kept their primitive function, which is to comfort the body in its struggle against the cold; for it is relatively poorly equipped for this. Our well-being is closely bound up with the heat around us, both in our professional occupations and in our leisure hours. Whether it be in officers or workshops, the work output, manual or intellectual can be improved by finding the most suitable temperature, taking into account the preference of the employees, but also avoiding too high temperatures in which microbes can breed. In short, amongst all the various reasons for summer migration to sunny shores, or simply for Sunday morning lie-ins, the search for warm surroundings is one of the most important.

In the energy field, especially in electricity, heat occurs at production and then exploitation level, in accordance with Carnot's principle. The natural forms of calorific energy, solar and geothermic, recently become a reality, are not at all competitive, because of their uncertain and localised character; however, they should play a more important role, especially in the conception and heating of living premises. Thermonuclear fusion has already been achieved on a small scale, in laboratory work, with the help of plasma temperatures of several million degrees, attained in virtual recipients created by strong magnetic fields: it should be mastered in one or two decades and will free man from the restrictions imposed upon him by the increased urgency of finding sources of energy. The degree of harmfulness in thermal pollution is harldy worth mentioning, except for the matter of the hot water discharged by he power stations, but it lies actually at a point common to all kinds of pollution, that of water which it potentializes or precipitates, and that of the atmosphere of which it is a by-product. The recommended economies in all fields of energy amount to a limitation in the production of heat from combustion, either directly, in the reduction of heat in buildings and improved insulation, or indirectly, by restricting the consumption of fuel, petrol or electricity.

In the industrial field, thermography is becoming increasingly important, for it provides original and economical solutions to complex problems, such as checking manufacture and running order, and detecting faults or breakdowns. From amongst the already numerous uses, let me quote as examples: in aeronautics, it measures the temperature of special alloys during manufacture, in order to avoid exceeding the critical temperature, detrimental to the mechanical properties; in the metal industry, it is used in the regular checks of the fire-proof linings of furnaces and converters, in order to prevent accidents and plan repairs; in electronics, it verifies the components of integrated circuits with the help of infra-red microscopes. In all those cases, the main advantage of the infrared techniques, is that they supply a global thermal vision, in real time, without touching the object, which is therefore not disturbed at all, and can be moving.

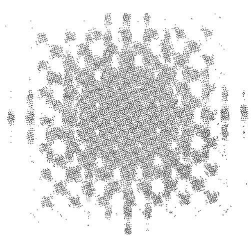
Food is also a matter for thermology: in the organism, food suffers metabolic loss, which generates heat, and energy requirements continue to be commonly described as « calories ». The problem of nutrition on a world wide scale, is bound up with that of demography, and is the object of cooperation by specialised international organisations, particularly F.A.O. and W.H.O. Preoccupation with calories may be one of the charms of the fair sex, and over-eating and some forms of dieting the luxury of rich countries, but millions of human beings in developing countries suffer each day from a calory and protein deficiency. For the purpose of improving food supplies, remote sensing techniques have recently been used to help the combined efforts of the agricultural experts, hydrologists, meteorologists and geographers. Remote sensing, a key element among the techniques covered by UNESCO's «Man and Biosphere » programme, analyses the radiation of the earth's surface in the infra-red spectrum and in the domain of micro-waves, by means of scanners aboard aeroplanes or satellites. The advantage of such methods lies in the fact that each element, and by extension each plant type, leaves traces of its own characteristics: temperature, composition, structure, in its emitted transmitted or reflected electro-magnetic radiation. This idea of « signature » can be applied to complex units, such as fields of cereals or shoals of fish, which can thus be counted rapidly and on a large scale. The same techniques permit early detection of attacks by parasites, faults in irrigation and the seat of fires.

Agriculture is fundamentally dependent on two thermoclimatic features, sunshine and rainfall, and the aptitude of the ground to accept one or the other. And there too, remote sensing satellites will help us from now on to consider the problem on the scale of the biosphere, from the point of view of describing the land, supervising farming, and forecasting the weather. Finally, numerous types of cultivation and breeding are carried out in premises specially planned and climatised with a view to maximum returns; the most widespread example is that of giant greenhouses, where the sun's rays supply not only the energy for biosynthesis, but indirectly the heat favourable to the germination and maturation of plants.

Indignation or exasperation may make us « not under the collar », . . . « Someone who is annoyed or exasperated can be said to be all het up » . . . We may live to regret something we said « in the heat of the moment » . . . Someone who is very angry is said to be « in a flaming temper ». . . There are really so many pejorative or abusive uses of the words conected with heat, some which we resort to when we get upset at work or in the hustle and bustle of town life! . . . But once at home with wife, children, or friends, at the fireside, in bed, or out in the sunshine.. . how pleasant is this heat; it is once more gentle, soft and soothing. An now and again, the warm and iridiscent colours of roses and young girls, and the warm and ardent reds of impressionist paintings delight our senses. For if heat is life, quickening our blood and improving our environment, it is also the fire of passion, the flame of tenderness, the light of friendship, and, in short, the reason for all our activity, today and probably for always . . .

Ladies and Gentlemen, it is a great pleasure but also a happy coincidence, to find ourselves gathered here in Bath, where the natural thermal springs have been an attraction and source of prosperity since Roman times. We shall not forget the warm welcome and the mysterious charm of this so typically Engilsh city which seems to have been immortalised in one of William Shakespeare's wonderful sonnets:

The little love-god, lying once asleep
Laid by his side his heart-inflaming brand,
Whilst many nymphs that vow'd chaste life to keep
Came tripping by: but in her maiden hand
The fairest votary took up that fire..
This brand she quenched in a cool well by,
Which from love's fire took heat perpetual
Growing a bath and healthful remedy
For men diseas'd; but I my mistress thrall,
Came there for cure, and this by that I prove,
Love's fire heats water, water cools not love.



ORIGINAL PAPERS

Thermography in malignant thyroid nodules

by TH. PLANIOL, G. FLOYRAC, J. F. DE MEYER

Nuclear Medicine and Biophysics, C.H.V. Bretonneau, Tours (France)

SUMMARY. Cervical thermography is all the more useful as it is coupled with radioactive and ultrasonic scanning in order to attempt a preoperative diagnosis of thyroid cancer.
This paper analyses the results in 59 cases of malignancy out of 364 patients which were examined by the three methods. Contrarily to benign lesions most of cancers are thermically hot. Thermic distribution is more significative than the increment of temperature. Pitfalls are the cysts associated with cancers, the large multinodular goiters, the microcancers.

Key words: thyroid nodules; ecbograpby; combined diagnosis of thyroid malignancy.

Cervical thermography provides a good picture of the temperature distribution over the superficial structures overlying the thyroid gland (and adjacent tissues). The procedure is easy and quick and it can be associated with the other physical non invasive methods to investigate biologic, morphologic, and structural alterations of the thyroid.

We use thermography together with radioisotopic and ultrasonic scanning [1, 2, 5]. These results are analyzed in 364 patients who came to surgery. So thermograms of malignant nodules can be compared to those of benign lesions examined during the same period of 18 months (1973-1975).

METHODS

Each year about 600 patients with a thyroid nodule or multinodular goitre are sent to our department in view of differentiating preoperatively cancerous from benign lumps.

After the clinical examination a pertechnetate scan makes a first distinction between isotopically hot and cold nodules [8], malignant nodules being usually cold. However pertechnetate may exceptionnaly show a hot area with a cancer. The normal value of the thyroxine index should then lead to repeat a control with iodine 13 1, which will correct the first conclusion. After the scan the patient with a cold nodule is scanned by ultrasounds in view to detect cysts. This is important because a completely liquid collection corresponds to a cold (hypothermic) area on the thermogram. Solid and partially necrotic masses are seen on the echographic pictures as a homogeneous or a heterogeneous assembling of echos. Bundles of echos associated with small silent areas suggest necrotic tissue. In both cases, the area of the nodule is different from the surrounding tissue, its boundaries being more or less clear [4, 6].

Except from special cases, thermography is carried out principaly on solid or heterogeneous nodules, not on large cysts. For this examination the patient is first left neck and breast uncovered 10 to 12 minutes in a room at an ambient temperature of 18°C. Then pictures of the neck are taken with an Aga Thermovision Unit 680. It can be helpful to observe the rewarming after having cooled the neck with alcohol. But we do not use this procedure for every patient. Pictures are in black, grey, and white. The temperature scale usually chosen is 1 to 10°C; the temperatures are measured with an accuracy of 0,5°C. The nodule is slighty encircled on the skin with a dermographic pencil. On the thermogram a mark is taken either with a fine guide which indicates the nodule's center or with a metallic ring which is not in contact with the skin. If necessary, and in order to be more precise, a polaroid photo of the neck is taken in the scanning position.

ANALYSIS OF THE CASES

The microscopic examination revealed 59 cancers out of 364 studied cases. In reality, for 7 of them, the malignancy did not seem certain to one of our histologists, who considered them as only potentially cancerous;

Tab. I.

	Number of cases
Papillary carcinoma	18
Follicular carcinoma	9
Mixed papillary and follicular carcinoma	9
Polymorph carcinoma	3
Sclerosing occult cancer	3
Trabecular carcinoma	2
Medullary carcinoma	3
Intrathyroid metastasis (hypernephroma) (bronchial epithelioma)	2
Anaplastic neoplasm	2

we discarded these 7 cases. Consequently, the analysis concerns 52 malignant diseases. They are classified by the histopathologists as indicated in the Table I.

Table II summarizes clinical data according to age, sex and physical examination.

For 14 patients, the nodule appeared 3 to 6 weeks before examination. For the other cases the nodule discovered accidentally. 5 patients with a solitary nodule had regional lymph nodes; 11 out of 12 multinodular goitres were old and 4 had recently grown.

Tab. II.

		Number of cases
Age (years)	under 30	*16*
	30 to 50	17
	over 50	19
Sex	male	44
	female	8
Palpation	isolated nodule	34
	2 or 3 separate nodules	6
	multinodular goiter	12

For the 12th case, the goitre developed after two operations, the first for toxic adenoma, the second for Graves disease.

Table III gives the results of the isotopic scanning.

Tab. 111

Palpation	***Radioisotopic scan***	***Number** of cases*
Solitary nodule	Hypoactive area	27
	Heterogeneous area	4
	Normal	1
2 or 3 nodules	All hypoactive	7
	One hypoactive	1
Multinodular goiter	Overall hypoactive	3
	Heterogeneous	9

In two cases with only one nodule at the physical examination radioactive scanning showed two hypoactive areas. So we can count at least 20 cases of multiple nodules. Nevertheless histopathological controls revealed only one cancerous focus, out of 10.

Apart from multinodular masses, pathological associations were:

Carcinoma

plus	- follicular adenoma	12
	- toxic adenoma	1
	- Hashimoto's thyroiditis	3

Intra-thyroid metastasis of a hypernephroma plus benign multinodular goiter 1

The echographic finding for the cancerous nodules are grouped in Table IV.

Tab. IV.

Eckograpkic pattern		**Number** of cases
Solitary nodule	- Solid mass (S)	*6*
	- cyst (C)	*3*
	- Pseudocyst (PC)	*6*
	- Heterogenous (H)	17
Multiple nodules	— All solid	6
	— Heterogenous	12

Let us emphasize that ultrasonic scanning allows one to distinguish solid cellular masses from normal thyroid tissue, and to visualize large cysts, as well as partial cystisation. Like cysts, pseudocystic patterns are echo free, but their boundaries are not clearly defined; they are due to rich liquid tissue like oedema, or may be follicular tissue.

RESULTS OF THE THERMOGRAPHY

In case of a thyroid nodule, the thermogram can be either normal, or show a variety of abnormal aspects.

The normal pattern

The study of the thyroid needs a thermographic scan which starts at the chin (chin up) and stops at the sternal superior limit (Fig. 1). Prominent areas such as the chin, the lower jaw, the clavicle, the salient fascicles of the muscles are normally cold areas. The hollow parts, above the sternum and clavicles are normally hot.

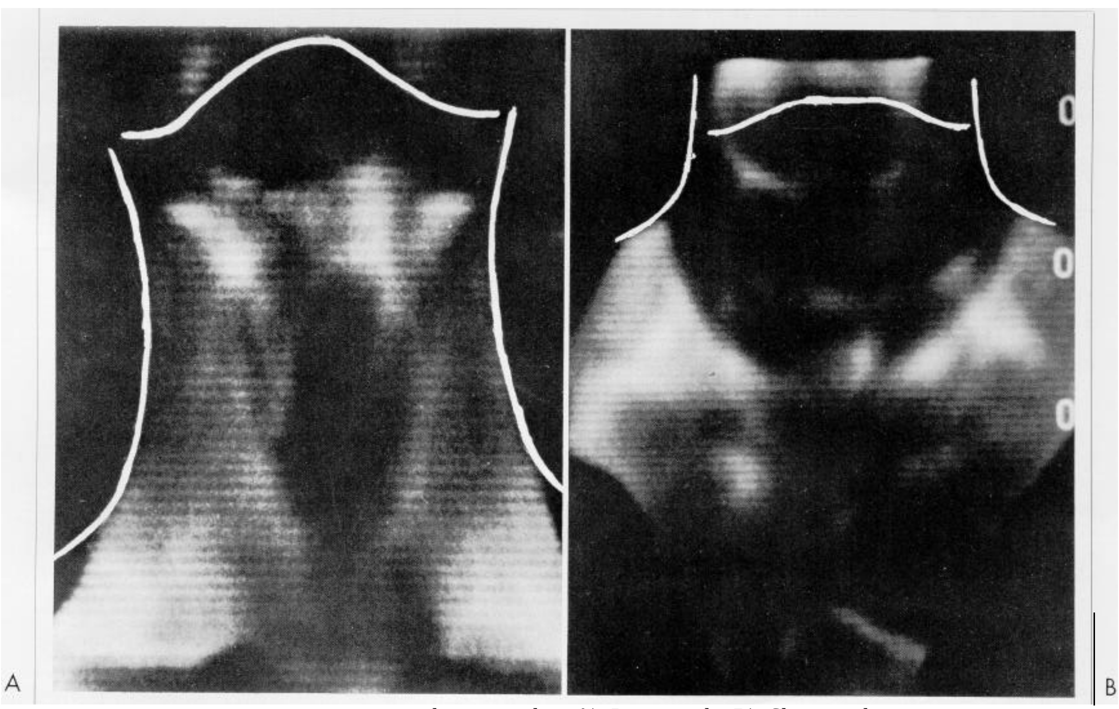


Fig. 1. Normal thermography: A) Long neck. B) Short neck.

The more these areas are depressed the hotter they are. The blood vessels of the neck can show up as hot courses, especially with thin subjects. The large and superficial veins may also give a hot picture.

One usually finds thermal symmetry. The extreme morphological variety of the neck explains why cervical thermograms can be so different from one subject to another, although the same patient, placed in the same conditions of temperature, keeps the same thermographic pattern.

The normal thyroid is usually not visible on the scan. 173 thermograms were considered as normal out of the 357 cases definitely kept for this study.

Thermographic anomalies

Hyperthermic lines. These are vertical following the course of the large blood vessels of the neck. The pattern can remain symmetrical, or it can be abnormally visible on both sides, but not symmetrical; or it can be marked only on the side of the nodule.

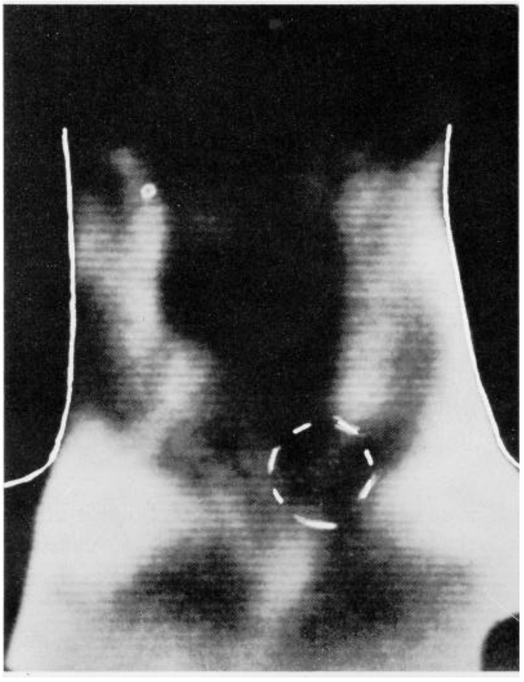


Fig. 2. Left nodule 2 months old, 4 cm in diameter. The nodule's area is cold but above and below there is a thick hot line like a vascular course. (T_1 type).

Hot area. Area corresponding to the nodule can be uniformly hot or warm, or it can be heterogeneous; it is sometimes cold at the centre and hot on the outside. A hyperthermic area is either a hot spot, or a larger zone; its boundaries can be either clear and regular, or irregular, ragged, star like. The abnormal area can overlap the nodule either moderately or considerably, covering then half the neck.

Several anomalies can be associated, for instance a hot or warm area and a vascular pattern, a hot spot and a large heterogeneous area.

Gradients of temperature. Considering the diagnostic value of the gradients of temperature in the case of breast carcinoma we started a similar study for the thyroid, measuring the differences of temperature between a hot point of the abnormal area and two other points, one on the chin as a reference (Δ_0) the second one on the symmetric area of the thyroid (Δ_1). In 15 cases of hyperthermic cancers average Δ_0 was equal to 2.3°C. In 34 cases of benign hyperthermic nodules the average Δ_0 was equal to 3.3°C. Moreover, when there was a large abnormal area, the difference with a supposed normal part of the thyroid was not significative, consequently we realized that this punctual measurement was of a poor value, while the temperature distribution pattern seemed much more discriminative.

We roughly classified the thermovisual patterns in 5 types, naming T_0 the normal image, and T_1 T_2 T_3 T_4 the abnormal aspects.

T_1 is characterized by one of the following abnormalities:

- hot or warm area on the nodule;
- small, hot and symmetrical course of blood vessels;
- cold area on the nodule's center with

either a hot boundary, or a vascular pattern (Fig. 2).

T_2 admits one of the following abnormalities :

- hot or heterogeneous area covering the nodule;
- asymmetrical course of the lateral blood vessels;

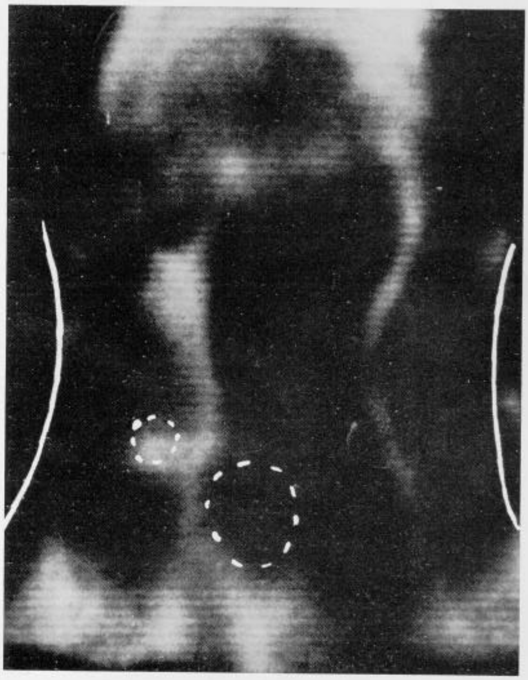


Fig. 3. Two nodules 1 month old, encircled. The right superior nodule is hot, with a marked vascular course on the right side. The isthmic nodule is cold. The right nodule was a follicular microcarcinoma (sclerosing-occult). The inferior nodule was a benign adenoma. (T_2 type).

- blood vessels only visible on the nodule's side (Fig. 3 and 4).

T_3 associates two of the aspects described above, or includes a larger abnormal zone:
- hot or warm nodular area associated to a hot vascular pattern on the same side as the nodule;
- hot or heterogeneous area which extends beyond the nodule associated or not with a vascular pattern:
- warm or cold area surrounded by hot zones, crossed by or crowned by a hot course (Fig. 5 and 6).

T_4 includes the largest alterations, exaggerating aspects described for T_3 sometimes resulting in anarchic aspects:
- globally hyperthermic or heterogeneous

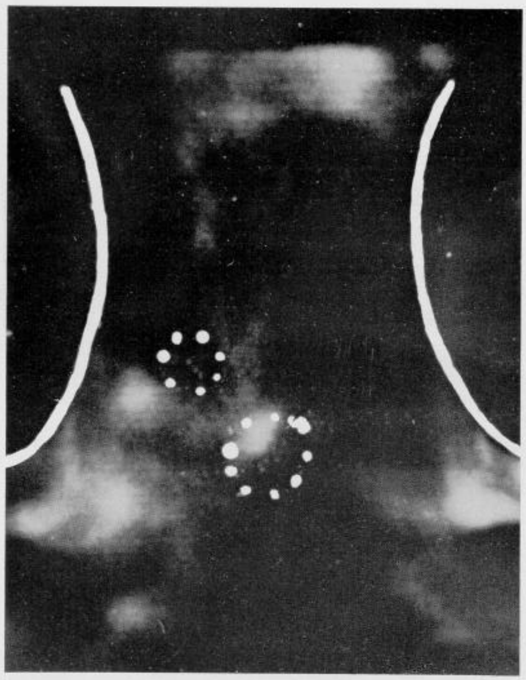


Fig. 4. Two nodules. The nodule on the right is old. The isthmic nodule is recent. (3 cm diameter). Both were cold at the radionuclide scan. Thermogram shows a hot spot on the isthmic nodule, the rest is cold. The hot spot is associated with a hot vascular pattern. Histology: the nodule on the right lobe was a benign adenoma. The isthmic nodule was a papillary carcinoma. (T_2 type. It could be T_3).

area extending beyond the nodule's boundaries, with a hot homolateral vascular course;
- hot area with irregular, ragged, or star-like boundaries on or at a distance of the nodule;
- large unilateral hyperthermic or heterogeneous zone;
- large hot or heterogeneous zone covering

all the lower part of the neck larger than the thyroid region (Fig. 7, 8, 9, 10 and 11).

For each of the type T_1 to T_4 various anomalies can be observed.

These different types of patterns were distributed between the different types of benign and malignant nodules as shown on Table V.

and T_4 patterns, 61% of cancers were involved, against only 10% of benign nodules.

Pratically, 79% of benign nodules are cold (T_0 and T_1) against 17% only of malignant nodules. As for the intermediary patterns, type T_2, they can be observed with equal frequency in both groups of benign and cancerous nodules. We have tried to correlate thermographic patterns to the can-

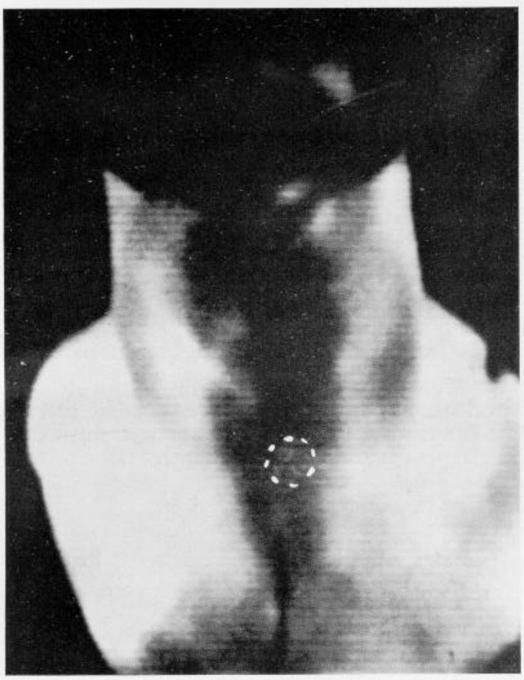


Fig. 5. Isthmic nodule 1.5 cm 1 month old. Thermic asymmetry. Star like image on the right side at a distance from the nodule which was pretracheal. Histology: papillary carcinoma. (T_3 type).

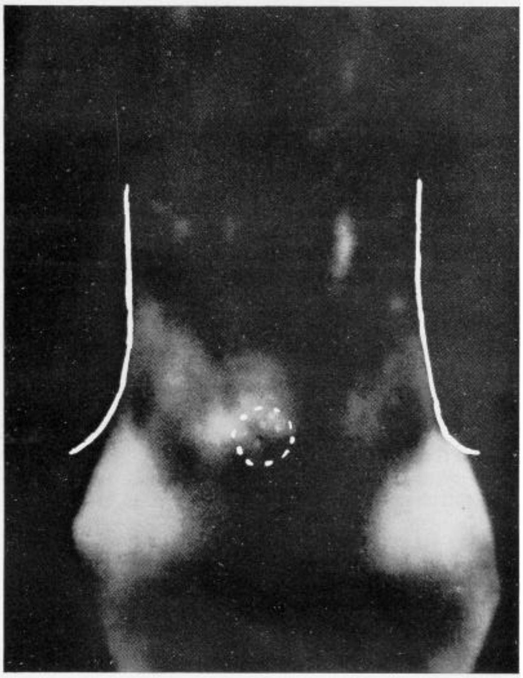


Fig. 6. Right superior nodule, 1 year old, with a 2.5 diameter and lymph nodes. Heterogeneous thermic image larger than the nodule area. (T_3 type).

The T_4 type of thermographic patterns was seen in 22 out of 52 cases of cancerous nodules, e.g. 44% against 5% for benign nodules (14 out of 305). If we add the T_3

cer's histological nature, its volume, and its physical structure. Tables VI and VII summarize these different confrontations.

It is clear from Table VI that in the varie-

Tab. V. Thermovisual category.

	T_4	T_3	T_2	T_1	T0	***Totale***
Cancer	22	10	11	5	4	52
Benign nodule	14	17	44	62	168	305
Potential malignancy		2	5		7	

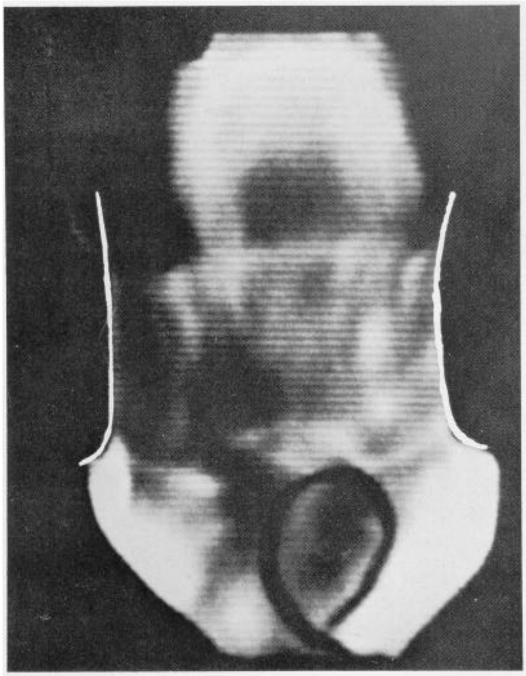


Fig. 7. 71 year old patient, already operated for a benign adenoma, second nodule with a 3 cm diameter, appeared 1 month before the examination. Nodule's area is cold, encircled with heat, plus large heterogeneous hyperthermic area covering half the neck. Histology: undifferentiated carcinoma. (T_4 type).

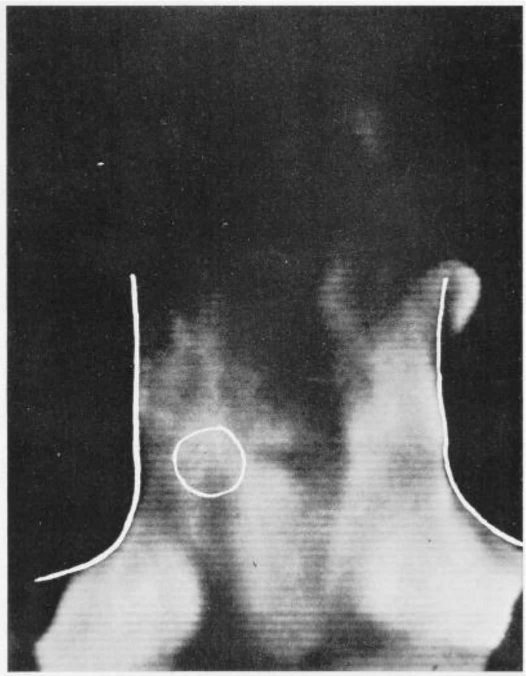


Fig. 8. Right nodule, 3 weeks old, with a 2 cm diameter. Star like hyperthermic image spreading far beyond the nodule. Histology: medullary carcinoma. (T_4 type).

Tab. VI. **Thermographic correlations.**

Nodule's diameter	***Number* of cases**	
	T_3 or T_4	T_0, T_1, T_2
$D \leq 10$ mm	4	11
$D \geqslant 15$ mm	28	9

Details of the 20 cases (T_0 T_1 T_2)	*No. of cases*
microcancers scattered through a goiter	2
cancerous lesion, with a 1-3 mm of diameter, at the boundary of a benign adenoma	
cancer, with a 4 to 6 mm diameter, associated to an adenoma	2
a 5 mm in diameter cancer at the boundary of a cyst	1
cystic cancerous nodules with a 9 mm diameter	2
solid cancer with a diameter of 8-9 mm isolated in a multinodular goitre	1
cancerous nodule with a diameter superior or equal to 20 mm	
— cystic	1
— partially cystic	3
— solid	3

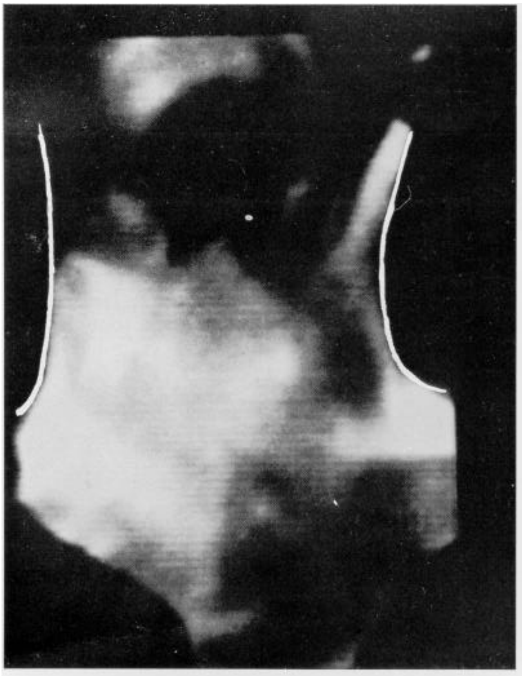


Fig. 9. Multinodular goitre 1 year old, with lymph nodes on the right side. 5 nodules isotopically cold. Thermogramm: large hyperthermic heterogeneous area. Histology: polymorph carcinoma. (T_4 type).

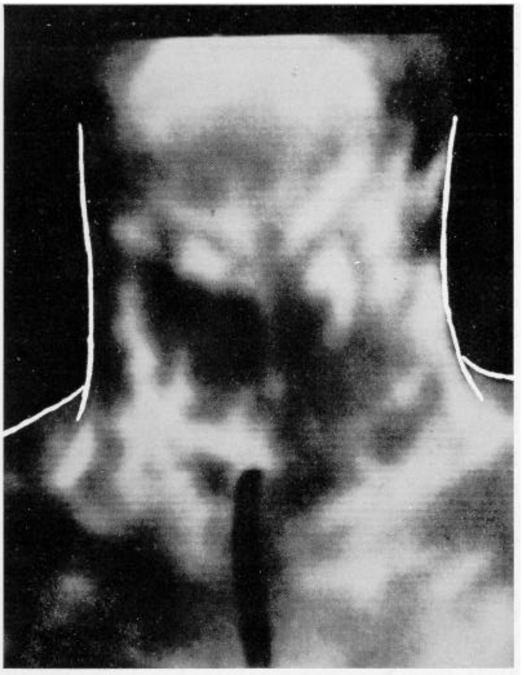


Fig. 10. Multiheteronodular goitre with signs of hyperfunction. Heterogeneous isotopic scan, with increased uptake on one nodular area. Thermogramm: high degree of hyperthermy on both sides, anarchic aspect. Histology: papillar and follicular carcinoma developed in a multiheteronodular goitre plus lymph nodes behind sternum. (T_4 type).

ties where the amount of cases is big enough to be statistically significative, 50 to 60% of the cases are hyperthermic. The microscopic aspect does not seem, at first sight, to influence the thermographic patterns.

We must add to these data that in 4 cases which were macroscopically similar to the previous cases there was a clear alteration of the thermogram, type T_3

- small cancerous lesions scattered in a goiter (2);
- cancerous lymph node 8 mm in diameter plus 2 small not palpable nodules (1);
- a 3 mm lesion at the boundary of a vesicular adenoma (1).

Table VII shows that hyperthermic cancers are usually solid or heterogenous at the ultrasound scanning. Three cases out of 28 seemed liquid or partially liquid. These were a solitary necrosed anaplastic carcinoma, a cystic mixed papillary and follicular carcinoma with a papillary vegetant nodule, and a follicular pseudo-cystic carcinoma.

6 out of the 9 warm or cold cancers which were echo-free or practically echo-free, were necrotic or cystic.

DISCUSSION

Some preliminary remarks are necessary before evaluating the importance of thermography as a diagnostic device.

Out of the 52 patients of our study, 32 only had solitary nodules; 7 of these had an adenoma associated to a small cancer located either on the border, or at the centre, or even at a distance of the adenoma. In 20 cases there were multiple nodules. In

Tab. VII. Thermographic correlations.

Thermovisual category	Number of cases	Echographic pattern	
		Solid or heterog.	cyst. / Ps cyst.
T_3, T_4	28	25	3
T_0, T_1, T_2	9	3	6

these cases we sometimes found one cancerous growth associated to benign adenomas, or even to .a hyperfunctionning nodule (1 case). Occasionally we found a microcancer or a few microlesions scattered through a multinodular goiter. Now and again we found several, solid or partially necrotic, cancerous lesions.

In these conditions it is natural that the thermographic scan should vary in a complex way according altogether to the volume of the cancerous growth, its tissular structure solid or necrotic, according also to the state of the tissue around it, alterations in vascularization, and the presence of associated lesions adenoma, cysts, thyroiditis, operation sequelae, regional lymph nodes.

As in the case of other physical external methods, the interpretation of the thyroid thermogram will probably be much more useful for the physician if one can take into account a certain amount of data so as to escape the biggest traps which can lead to falsely positive or falsely negative diagnoses.

The study of 305 thermographic scans of benign nodules showed that 10% of these are hyperthermic and therefore falsely positive (Fig. 12 and 13). These aspects are usually seen with big adenomas (over 2 cm's diameter) or nodular chronic thyroiditis, or multinodular goitres; 50% of the latter are hyperthermic.

The hot area of cancerous nodules is usually definitely larger than the nodule, this is hardly ever the case with benign hot nodules. A cancerous hot area is often heterogeneous, poorly circumscribed, irregular, star-like, or associated to a large hyperthermic homolateral zone. We must emphasize that in the present series, the proportion of false positive is particularly high because nodules with a hot area, lead more often to the operation than the non hyperthermic lumps.

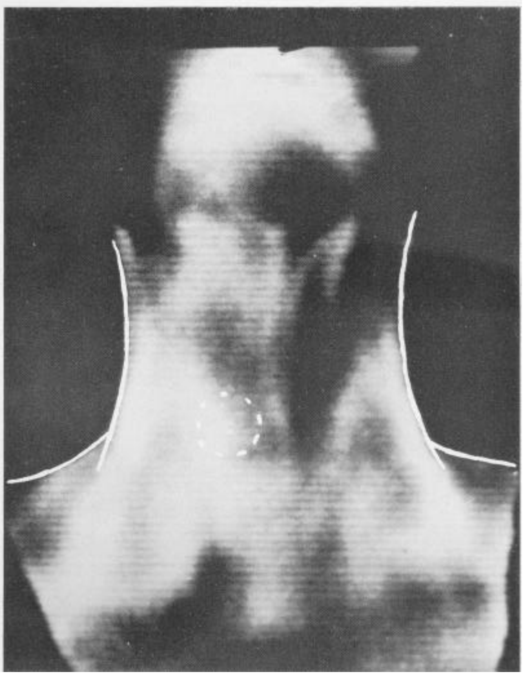


Fig. 11. 1 month old nodule in the inferior part of the right lobe, with a 2.5 cm diameter. No lymph nodes. Large heterogeneous hyperthermic area on the right side plus vascular course. Histology: mixed papillar and follicular carcinoma. (T_4 type).

Intermediary patterns, T_2 type, exist in similar proportions in both categories of nodules, and this means they have no significance as far as malignancy is concerned.

Altogether, T_3 and T_4 patterns, were found in 60% of the cancers we studied against 10% in the benign nodules. Nodules with this pattern have a great likelihood of being malignant; this is even truer for a small or solitary nodule.

Certainly, the percentage of negative or non significative thermographic results is still too high 40% to be able to say they are false negative diagnoses. The results of the other investigations can lead to doubt of a negative thermographic result without however excluding the hypothesis of a malignancy.

Apart from the presence of a masking cyst which can be revealed by ultrasounds few physical data permit to predict why a solid cancerous nodule with a diameter superior to 10 mm should not be hyperthermic. For a small carcinoma isolated or associated to a benign adenoma we are hardly suprised to observe non significative alterations on the thermogram.

Finally, in our study, after all the preoperative investigations except puncture, we suspected a cancer in 77% of the cases where there was one, and we throught there was probably no cancer in 6% of these same cases. Our conclusion was incertain in 17% of these cases. During the same period 8% of the benign lesions were thought to be malignant. We found no explanation for the hyperthermic character of some benign adenoma.

CONCLUSION

In order to attempt a preoperative diagnosis of thyroid cancer cervical thermography can be helpfully combined to physical examination, radionuclide and ultrasonic scanning of the neck. We found 60% out of 52 cancers with hyperthermic areas while about 60% of the benign nodules do not noticeably change the thermographic pattern. The most significative features associated with the malignancy lie in the heterogeneous distribution of the temperature over the abnormal area. Several patterns can be observed, and generally the surface of the anomalies is larger than the nodule’s area.

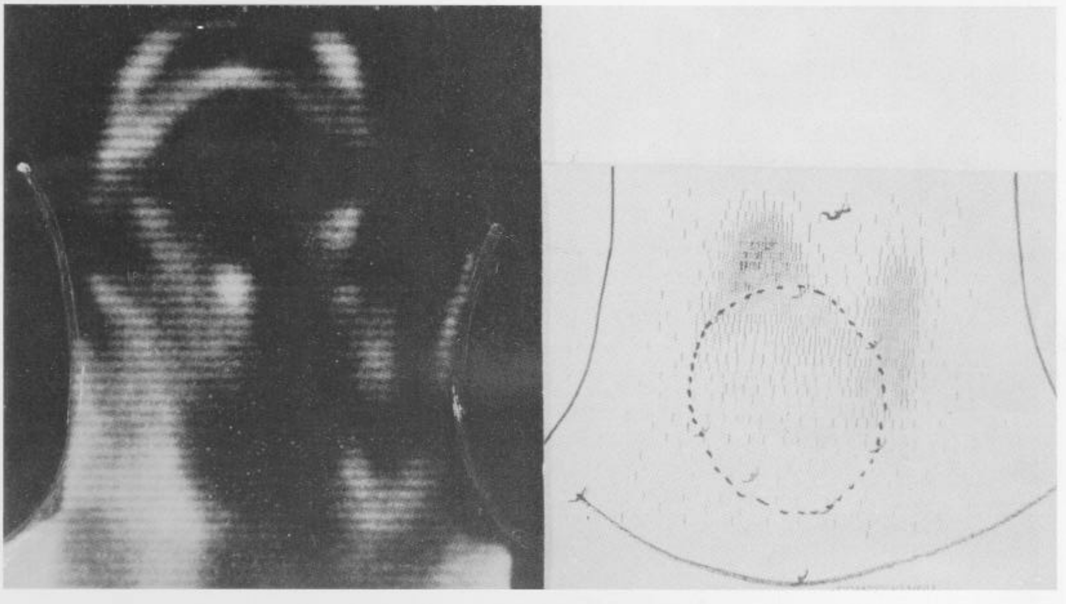


Fig. 12. Hyperthermic adenoma; hyperthermy is moderate compared to the size of the adenoma. encircled on the scan.

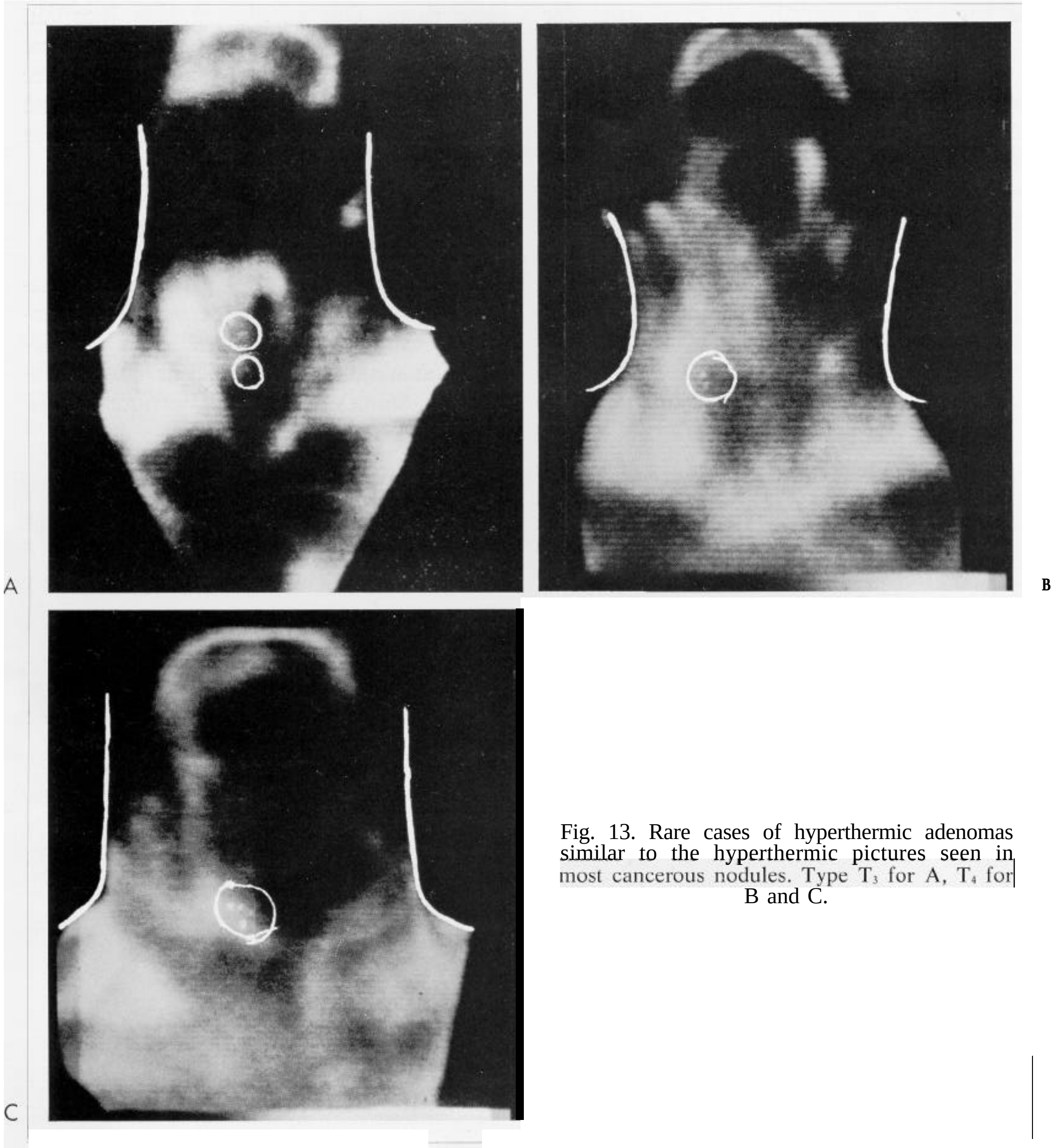


Fig. 13. Rare cases of hyperthermic adenomas similar to the hyperthermic pictures seen in most cancerous nodules. Type T_3 for A, T_4 for B and C.

False positive (8% of benign lesions out of 305 cases) were due to multinodular goiters subacute or chronic thyroiditis and some large adenomas. False negative or non significative thermograms, were due to the smallest cancers with a diameter under 6 mm, to a cyst or benign adenoma which masked a carcinoma. In 3 cases a solid tumor with a diameter over 15 mm we found no explanation for the absence of hyperthermy. It does not seem that the hystological nature of the cancer could influence the thermography, but larger statistics are necessary to evaluate this parameter.

Anyway the thermography cannot be considered as an autonomous method for the diagnosis of thyroid cancer [3, 7]. On the contrary, in a overall physical investigation it brings a real contribution to help the surgical decision, if one thinks that every suspected thyroid cancer must be operated.

REFERENCES

1. **Besnard** J. ***C.: Conduite à fenir, en exploration fonctionnelle, devant un nodule thyroidien.*** Thèse de Doctorat d'Etat en Médecine, Tours, 1973.
2. **Besnard** J. C., **Planiol** Th., **Floyrac G.: MC**-thodes Physiques dans 1'étude des nodules thyroïdiens. ***La Vie Médicale,*** 2, 118-124, 1974.
3. **Homesley** J., **Kovaleski** B., **Vanags K., Schrayer** M., **Franco** J.: Thermography in the evaluation of cold thyroid nodules. J. ***Nucl. Med.,*** 16, 536-537, 1975.
4. **Perlmutter G. S., Goldberg** B. B., **Charkes** N. D.: Ultrasound evaluation of the thyroid. ***Seminars in Nuclear Medicine, 5, 299-305. 1975.***
5. **Planiol** Th., **Garnier G., Pourcelot** L.: L'association de la thermographie et de l'éhographie bidimensionnelle à la scintigraphie dans l'étude des nodules froids thyroïdiens. ***Ann. Radiol.,*** 14, 695, 1971.
6. **Rasmussen S. N., Christiansen** U. J. B., **Jorgensen** J. S., **Holm** H. H.: Differenciation between cystic and solid thyroid nodules by ultrasonic examination. ***Acta. Chir. Scand.,*** 137, 331, 1971.
7. **Rocchi L., Riva** P.: Le rô1e de la thermographie dans 1'étude des nodules thyroidiens. ***Journal de Radiologie, 56, supplément*** I, 58, 1975.
8. **Turner** J. W., **Spencer** R. P. Thyroïd carcinoma presenting as a pertechnetate « hot » nodule, but without 131 I uptake: case report. J. ***Nucl. Med., 17, 2-23,*** 1976.

Effects of surface emissivity and viewing angle on errors in thermography

by J. A. CLARK

University of Nottingham, Nottingham (England)

SUMMARY. The effects of surface curvature on errors in thermography are considered. Use of the linear approximation of the Stefan-Boltzmann relation suggests that reflected radiation will he responsible for much of the error in estimation of surface temperatures by thermography, and that at oblique angles of view temperature anomalies may be obscured without showing large errors in absolute temperature.

Key words: thermography; errors; experimental work.

The effects of surface curvature on the radiation emitted from a curved surface reaching a thermal scanner, have been previously discussed in detail by Watmough, Fowler and Oliver (1970). These authors showed that over a wide range of surface emissivites the apparent emissivity of a curved surface should vary very little for angles of view between the normal and $\pi/4$, but that at greater angles progressively increasing differences would be expected between the signal incident on the detector from an element of emitting surface at an angle ϕ to the line of view and that incident from a point at the same temperature viewed along the normal. Though thermal scanning is perhaps now less promising as a tool in cancer detection, many other clinical uses have been proved, for example in the detection and monitoring of treatment of joint lesions and vascular anomalies, quantification of the likely causes of error in thermography therefore remains important. The present paper discusses a further source of error in thermography due to variation in the reflected radiation, which may in many circumstances exceed that considered by Watmough et al, and will always occur with it.

Theory

The relation between the emissivity of a surface at normal incidence ($_{o\lambda}$) and its refractive index (n_λ) at the same wavelength (Coulson 1955) is:

$$1 - {}_{o\lambda} = \left(\frac{n\lambda - 1}{n\lambda + 1}\right)^2 \qquad (1)$$

from which Watmough et al obtain:

$$\varepsilon_{\phi\lambda} = 1 - \tfrac{1}{2}\left\{\frac{\beta - \cos\phi}{\beta + \cos\phi}\right\}^2 \left\{1 + \left[\frac{\beta\cos\phi - \sin^2\phi}{\beta\cos\phi + \sin^2\phi}\right]^2\right\} \qquad (2)$$

(In the original paper, this equation appears incorrectly with the index inside the first bracket). Here β is $(n_\lambda^2 - \sin^2\phi)^{1/2}$, where ϕ is the « Angle of View » between the normal to the surface and the line of sight of the scanner. Watmough et al (1970) give error curves of differences in energy emitted, based on this equation, for a range of surface emissivities. However, Steketee (1973) has since confirmed the results of Mitchell et all (1967) which show that the overall emissivity of the human integument is close to 0.98. This value has therefore been used in producing Fig. 1 which shows the predicted variation of emissivity with viewing angle for skin, since Watmough & Olive (1968 a, b) obtained similar values for 2-5 pm radiation.

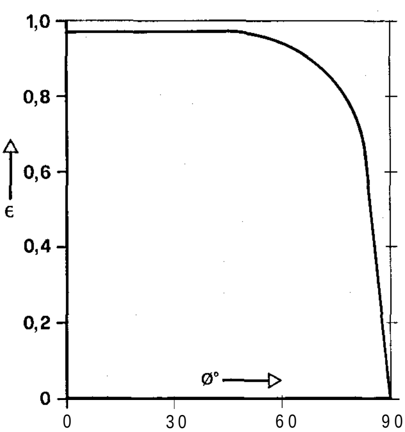


Fig. 1. Variation of emissivity ε with angle of view predicted by theory for a smooth surface with $\varepsilon = 0.98$ at normal incidence.

If we denote the skin temperature by T_s, and that of the surrounding environment by T_e, the « black body » radiation appropriate to the skin temperature is:

$$E_b = \sigma T_s^4 \qquad (3)$$

and the radiation incident on the skin from the environment:

$$E_e = \sigma T_e^4 \qquad (4)$$

Most contemporary scanners are sensitive to energy in the waveband from 2 to 5 µm. However for the present purposes we will neglect the distinction between the total radiation reaching the scanner and that in the waveband to which it is sensitive, justify this later. The radiation reaching the scanner which is emitted by the surface is then:

$$E_s = \varepsilon \sigma T_s^4 \qquad (5)$$

so that the difference (AE) from the black body emission appropriate to surface temperature is therefore given by:

$$\Delta E = E_b - E_s$$
$$= (1-\varepsilon)\ \sigma T_s^4 \qquad (6)$$

However there is a second source of radiation which reaches a scanner, as radiation from the surroundings will also be reflected towards a scanner by the surface. In any waveband the emissivity and absorption of a surface are equal, so that the skin will absorb a fraction of the radiation incident from the surroundings. More important in the present context is the reflection of the remainder, so that, assuming the environment is an isotropic source of radiation, the quantity of radiation from the environment reaching a scanner after reflection from the skin will be:

$$E^1 = (1-\varepsilon)\ \sigma T_e^4 \qquad (7)$$

The difference between the black body radiation equivalent to skin temperature and that received by a scanner viewing the surface is therefore:

$$\Delta E = (1-\varepsilon)\ (\sigma T_s^4 - \sigma T_3^4) \qquad (8)$$

so that ΔE will be negative if $T_e < T_s$.

Clinical thermographic examinations are usually carried out in rooms where the temperature differences between the subject and the environment are fairly small. Either the Stephen-Boltzman equation, or the higher power dependence of E on T at shorter wavelengths, may by linearised for small temperature intervals to the form:

$$AE = CAT \qquad (9)$$

with acceptable errors for the present purpose. Equation 8 then becomes

$$\frac{AT}{T_s - T_e} = (1-\varepsilon) \qquad (10)$$

where AT is the error in the estimation of the absolute temperature. The locus is a simple straight line (Fig. 2) which predicts that the error of a thermographic temperature measurement is proportional to:

(a) the deviation of the surface emissivity from unity

(b) the difference between the temperature of the skin and environment.

For example, for a 10°C difference between ambient temperature and skin temperature, the error in the estimation of the absolute skin temperature at normal incidence will be 0.2 K. This is unimportant because temperature anomalies are the object of investigation, and the emissivity is effectively constant at 0.98 for values of ϕ between the normal and 45" and only just falls below 0.95 at 60°. At $\phi = 60°$ the error due to a 10°C difference from ambient temperature will be approximately 0.6 K, for $\phi = 70°$ it will rise to 1.3 K and close to the tangent the indicated temperature becomes that of the surrounding environment. The predicted variation of error AT with ambient temperature is shown in Fig. 3 for environmental temperatures at 5 K intervals from (T_s+5) to (T_s-15).

The error can also be considered in a different way, which is perhaps more relevant to the clinical case: the signals of interest in the clinical applications of thermography are anomalies in the temperature distribution. The variation of T with ϕ can also be regarded as giving the *proportion* of the true signal which originates from the surface inspected. For the lower curve of the female breast in mammography, or for the inner surfaces of legs, the error in the *absolute* temperature may be relatively small, since much of the skin's « environment » is other tissue at a similar temperature, but the signal from an anomaly will be obscured almost as effectively as that from the outer tangential surfaces of the body due to the reduced emissivity at glancing angles.

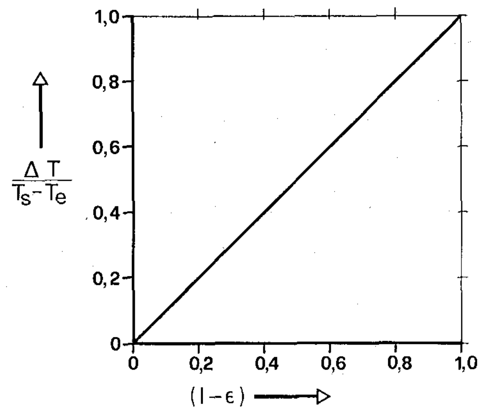


Fig. 2. Variation of the ratio of temperature error AT to the difference between true skin temperature and environmental temperature, as a function of skin emissivity. Locus predicted- by linear approximation of radiative exchange.

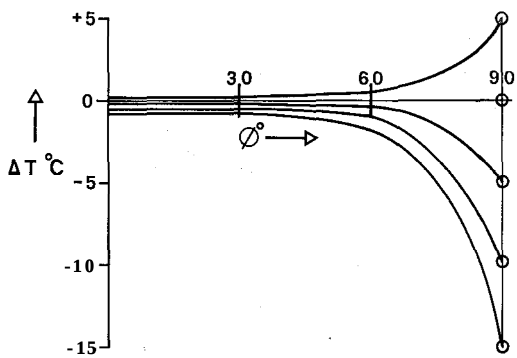


Fig. 3. Predicted variation of temperature errors of thermographic observation against angle of view. Lines are shown for ambient temperatures at intervals of 5°C from 5°C above skin temperature to 15°C below skin temperature.

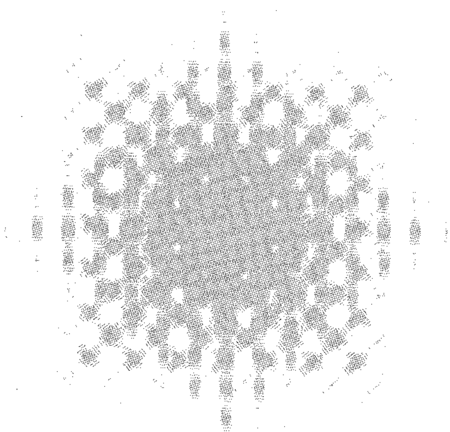
Conclusions

The present paper supports the conclusions of Watmough et all (1970) that errors in thermographic observations of skin temperature distributions are likely to be small for angles of view up to n/4. However, it is demonstrated that the thermal radiation environment of smooth anatomical surfaces will have a major influence on the error in temperatures observed for angles of view greater than n/4, and that such errors are likely to be proportional to the difference between the temperature of the skin of the subject and his environment, and to the deviation of the skin emissivity from unity.

REFERENCES

1. MITCHELL D., WYNDHAM C. H., HODGSON T., NABARRO F. R. N.: Measurement of the total

normal emissivity of skin without the need for measuring skin temperature. Phys. ***Med. Biol.*** 12. 359-366. 1967.
2. STEKETEE J. S.: Spectral emissivity of skin and pericardium. Phys. ***Med. Biol.,*** 18, 686-694, ***1973.***
3. WATMOUCH D. J., FOWLER P. W., OLIVER R.: The thermal scanning of a curved isothermal surface. ***Phys. Med. Biol.,*** 15, l-8, 1970.
4. WATMOUCH D. J., OLIVER R.: Emissivity of human skin *in vivo* between 2.0 µm and 5.4 µm measured at normal incidence. ***Nature,*** 218, 885-886, 1968.
5. WATMOUGH D.J., OLIVER R.: Emissivity of human skin in the waveband between 2pm and 6µm. Nature, 219, 622-624, 1968.
6. WATMOUGH D. J., OLIVER R.: Wavelength dependence of skin emissivity. ***Phys. Med. Biol.,*** 14, 201-204, 1969.



STATE OF ART

Disorders of the cardiovascular system: the thermographic technique

by T. WINSOR[1] and D. WINSOR[2]

[1] *University of Southern California School of Medicine;* [2] *Memorial Heart Research Foundation, University of Southern California School of Medicine; Los Angeles (USA)*

SUMMARY. Thermography is ideally suited to the study of the peripheral circulation. In some cases the thermograph is the primary instrument for such studies. For example, circulation of the individual toes and fingers can he studied effectively with this instrument, some specific heat patterns suggesting the etiology of disease. For example, osteoarthritis, rheumatoid arthritis, synovial membrane infections of the hand. However, most pictures are non specific and suggest anatomical areas of altered temperature or physiologic changes in certain parts of the body consistent with a variety of different disease states. Thermography should he a part of every non invasive vascular laboratory where studies on the peripheral circulation are being made. The arterial circulation from the neck to the head, venous thrombosis and peripheral arterial diseases at the extremes of the circulation are among the useful areas for this device.

Key words: thermography; peripheral circulation; arteries; veins and lymphatics.

In some cases the thermograph is the primary instrument for the study of the circulation. Arterial disease of the fingers and toes is often detected most readily thermographically. Also, for screening for cerebral vascular disease, this instrument is of primary importance. The purpose of this paper will be to point out the value of thermography in the cardiovascular diseases which will include disease of the heart, chest and lungs as well as those of the upper and lower extremities, as well as the arterial circulation of the head.

INSTRUMENTS AND METHODS

We used the Barnes black-and-white scanner, the Barnes color instrument, the AGA Thermovision black-and-white scanner and the General Electric Spectrotherm 1000 black-and-white instrument. All instruments were capable of giving satisfactory information for their intended uses. The Spectrotherm has a high resolution, the AGA a medium resolution, and the Barnes a lower resolution. The time taken to record the photographs varied from a fraction of a second to two seconds with the Spectrotherm and AGA instruments, to four minutes for the Barnes instrument. For many studies, the patient was able to lie quietly, and the longer scan period was thus not a hindrance.

The color display of the Barnes instrument, the first color instrument available, was especially useful for studying the peripheral circulation. It appears that the isothermic display on a color basis is well suited to the peripheral circulation: in contrast, high-resolution black-and-white may be preferred when studying the breasts and other areas where details of vascular patterns must be displayed. The pseudo-color technique was useful for converting black-and-white to color pictures [1]. For purposes of this publication, the color displays were photographically converted to black-and-white; in this process some definition is lost.

The patients were studied in a clinic environment. The studies were carried out in a minimal-draft room at 73°±1.5°F after 10-20 minutes of equilibration. For studies of the cerebral circulation, in which the forehead is uncovered, less equilibration time was generally needed; for legs or arms which had been covered by clothing, however, a longer period of equilibration was needed after removal of the clothing.

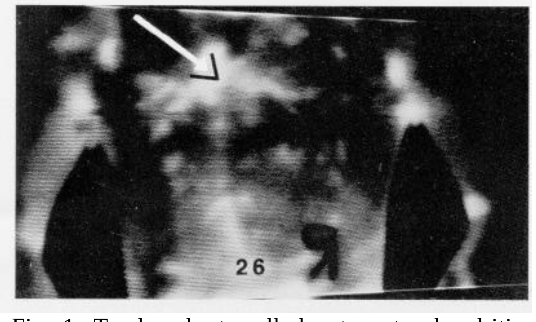


Fig. 1. Tender chest wall due to osteochondritis (arrow). Clinically the warm area was tender.

HEART AND CHEST

Generally, the heart is difficult to study thermographically; in certain conditions, however, cardiovascular abnormalities emit a characteristic heat pattern. For example, coarctation of the aorta shows an unusually warm upper chest wall and upper back due to the rich collateral circulation above the coarctation [2]. The collateral arteries are close to the skin, and increases in skin temperature occured in these areas.

Pericardial effusion of certain types, when the effusion was sterile and of large amount, sometimes produced a cool precordial area; a septic pericardial effusion may not produce a similar result. It appears that the aseptic effusion serves as a heat shield which prevents the heat generated by the metabolism of the heart from reaching the anterior chest wall.

It has been stated in the literature that large pulmonary infarcted areas show a cool chest area with respect to the normal side, whereas pulmonary infection, such as lobar pneumonia, shows an increase in chest temperature on the infected side. We have had little experience with these disorders, but they deserve further study [3].

Pacemakers which had been subcutaneously implanted were studied to determine if there was a change in thermographic pattern. The pacemaker sites normally became cool a few weeks after insertion and after healing of the found. However, certain patients had persistently hot pacemaker sites which represented chronic inflammatory reactions around the pacemakers. In one case, it was necessary to replace the pacemaker because of this inflammatory reaction. The electronic circuitry was not a cause of pacemaker heat in these cases.

The tender chest wall syndrome was usually difficult to identify (Fig. 1). Generally, there was acute tenderness clinically around several of the costochondral junctions. In about 25% of the cases, this area was warm thermographically; in one case, a bone scan showed evidence of costochondritis with increased uptake of radioactive material over the warm spot. This ultimately turned out to be metastatic carcinoma of the pancreas. Sternotomy scars which resulted from open chest coronary bypass surgery were studied at intervals after surgery. Immediately and a few weeks after surgery, these scars were warm. However, the scarred area returned to normal temperature remarkably rapidly, often within a month. In certain cases, hot areas along the incision were observed. These represented local areas of irritation caused by protruding wires, sometimes with abcess formation, which required reopening of the wound.

DISORDERS OF THE UPPER EXTREMITIES

The diseases are divided into abnormalities of the arteries, the veins, the lymphatics, the nerves, the soft tissues and joints and other conditions. Some of the conditions are of vascular origin, while other5 are not. When the thermogram5 were being read, it became necessary to distinguish, if possible, the vascular from the nonvascular states. This often had to be done on the basis of the clinical examination, since the heat patterns were often not specific [5, 6, 7].

The arterial diseases [6] produced lesions which were either cool or hot. Cool lesions were been with acrocyanosis, whereas warm lesions, such as arteriovenous fistulae, showed heat over the fistula [8]. Of the venous disorders, thrombophlebitis produced a heat pattern which was either localized or diffuse. Superficial thrombophlebitis, such as that from a chemical injury, was often localized and warm, whereas deep vein thrombophlebitis of the axillary or brachial vein often gave total heating of the entire limb [9]. Lymphatic abnormalities showed normal temperatures with chronic inactive lymphedema, such as lymphedema preacox; lymphedema associated with lymphangitis, on the other hand, was hot, and was also difficult to differentiate from acute deep vein thrombophlebitis.

Lesions of nerves in which irritation was the major phenomenon produced coolness of the limb distal to the level of irritation; however, there was often a warm lesion at the site of the irritation itself. For example, a brachiitis due to muscular strain produces heat in and around the neck and shoulder, with a cool arm and hand. The carpal tunnel syndrome, which in itself produces a cool digit because of nerve irri-

Fig. 2. Synovial membrane infection produces triangular temperature pattern which is characteristic of this condition.

tation, has been generally difficult to recognize because it is often associated with arthritis, which produces warm extremities. Hemiplegia produces a cool limb because of disuse with a low metabolism in the paralyzed part. Peripheral neuropathy produces drying with associated increased heat in peripheral areas, as does a sympathectomy. Radiculitis from the back, such as from a disc, often produces a warm back and a cool limb as measured thermographically. Acute soft tissue injuries, such as tendonitis or contusion, produce warm areas.

Other conditions, such as cervical rib compression and costoclavicular syndrome, are very irregular in their temperature responses. Often there is no temperature abnormality [4].

Hyperhydrosis produces cooling as a result of sweating. Fractures produce warm lesions. Peripheral vascular drugs such as Roniacol (nicotinyl acid tartrate) produce peripheral warming [9].

Warm patterns of the upper extremities

Pattern recognition, when possible, is important in reading thermograms. Unfortunately, different disease states often produce similar patterns; thus the clinician must, consider the thermal pattern in light of his general knowledge of the patient. There are certain thermal patterns, however, which strongly suggest various disease states.

, Warm proximal interphalangeal joints are seen in arthritis - especially rheumatoid arthritis - when it is in an active phase; the picture was rather specific. Warm distal interphalangeal joints suggest osteoarthritis.

A warm triangular pattern on the dorsum of the hand was characteristic of synovial membrane infection (Fig. 2). Such infections often appear first as a sinus at the distal phalangeal joint. This sinus becomes infected, and early in the course of the disease, a single joint becomes infected. As the infection spreads along the synovial space, the typical triangular picture of synovial membrane involvement in seen.

Warm areas of one wrist could be arthritis or sprain; when both wrists are involved and are warm, however, it is more likely that arthritis is the cause of this heat abnormality.

A warm finger or fingers, on one hand only, was characteristic of paronychia, fracture, sprain or contusion.

A hot palm or dorsum of the hand was a nonspecific finding seen with AV fistulae, trauma and other conditions.

Hot fingers with respect to the palm were seen in normally dilated individuals; this finding also appeared in cases with extreme vasodilatation like that which sometimes occurs with Weir-Mitchell's disease or after administration of drugs.

Cool patterns of the upper extremities

« Bite » defects of a fingertip were seen in diabetes and Buerger's disease as well as in disseminated lupus and early arteriosclerosis. The bite defect is important to recognize, since early disease often manifests itself at the most distal parts of the circulation. Thus tell-tale lesions on the tips of the fingers may signal the existence of more serious disease elsewhere in the body.

Localized cool spots on a hand with normal temperature patterns of the fingers were seen with old skin grafts, old scars, old hematomas and dermoid cysts.

Bilateral coolness of both hands and the fingers was seen normally and with ergotism, smoking and hyperinsulinism. Use of dynamic thermography is of extreme importance in these cases to note the rate of cooling or heating of the hands when employing body heating or cooling. Bilateral and equal rates of cooling or heating of the hands signify a bilateral and equal vascular state of the hands, which occurs normally. If the hands differ in rates of response to body heating, vascular disease is usually present.

Bilateral cool fingers with normal temperatures of the palms and the hands were seen with primary Raynaud's disease [11] and acrocyanosis.

Unilateral coolness of the hands, wrist and fingers was seen for example, with arterial occlusion [12]. This finding was characteristic of brachial artery occlusion with the temperature line approximately at the wrist. With axillary or subclavian artery occlusion, the temperature line was often at midbrachial level.

Coolness of one finger on one hand was often traumatic.

Coolness of certain fingers on both hands was common in many disease5 - scleroderma and diabetes.

DISORDERS OF THE LOWER EXTREMITIES

Thermography of the lower extremities can employ a technique that is either static or dynamic. Static thermography is generally used to determine heat patterns which might suggest diseases of the arterial, venous or lymphatic systems. Dynamic thermography is utilized primarily to isolate and display the perforating veins which help burgeons visualize those which are not readily palpated or seen.

The patients observed in this series included those with diseases of arteries, veins, lymphatics, nerves, soft tissue and joints, and other conditions. These lesions were divided into those which characteristically were cold and those which were warm. It should be kept in mind, however. that the same disease may be cold in one phase and warm in another; sclcroderma, for example, may produce cool digits, but a flareup of the condition associated with increased metabolism causes the skin to become inflamed and results in a warm lesion in place of the cool one. Similarly, lymphedema was often two-phased; the temperature was normal in the inactive phase but increased during the stage of inflammation.

Warm lesions of the lower limbs

In the area of the lower abdomen and groin, thrombophlebitis often involved the pelvic vein5 or the femoral vein (Fig. 3); these produced significant amounts of increased heat [9]. In the leg, deep vein thrombophlcbitis may be confined to either the calf or the thigh area. In certain phases of thrombophlebitis of the deep vein5 of the thigh, the thigh may be warm and the foot cool. This temperature difference may be caused by diversion of blood from the toes to the area of increased metabolism, or it may come about as a causalgic reaction when the nerves are involved in the phlebitic process. Stasis dermatitis is a consequence of either deep vein thrombosis or severe venous insufficiency, which results in capillary hypertension, skin changes and increased heat. Often, the stasis dermatitis produces increased heat which lasts for years. When ulceration occurs, the ulcerated area itself is wet and a thermogram of the ulcer is cool due to evaporation.

Perforator veins were readily identified and were warm [13].

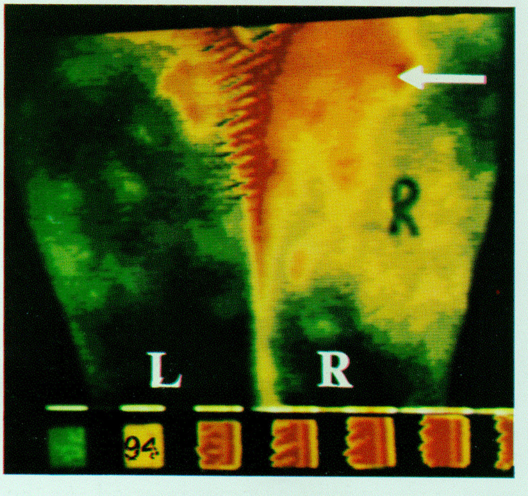


Fig. 3. Iliofemoral vein thrombosis producing heat in the region of the groin and upper thigh.

Hot lesions arc seen when sprains, contusions, infections and arthritis are present. Burns [10, 14] and frostbite [10] were warm at times. The rate of healing of burns could be evaluated [15].

Gout gives hot lesions of the toes; however, these lesions cannot be differentiated from those produced by acute arthritis or fractures. Local conditions of the toes, such as bacterial or fungus infections, paranychia and fractures, often produce hot lesions.

The healing process after calf venous thrombosis, is readily evaluated through the use of aerial thermograms.

Cold lesions of the lower extremities

In the hip area, hypogastric artery occlusion produces a picture that shows cooling. This is often important in handling patients with impotence or with vascular disease in and around the aorta or the large arteries. Nerve root irritation can sometimes produce cooling in this area; this must be differentiated from arterial occlusion on a clinical basis. Aortic occlusion (Leriche syndrome) produces thigh cooling bilaterally. Lesions in the common femoral artery produce temperature lines in the lower thig area. Ostructive lesions such as superficial femoral artery and popliteal artery occlusions, produce temperature lines at the mid-calf level. Occlusions of arteries of the dorsum of the feet are characterized by an inability to visualize the dorsalis pedis artery. Individual toes are often cold when digital artery occlusion is present - as in peripheral arteriosclerosis, for example. When the lesions are scattered widely, foot microemboli are considered. A warm foot often follows successful posterior tibia1 nerve block. An irritating lesion such

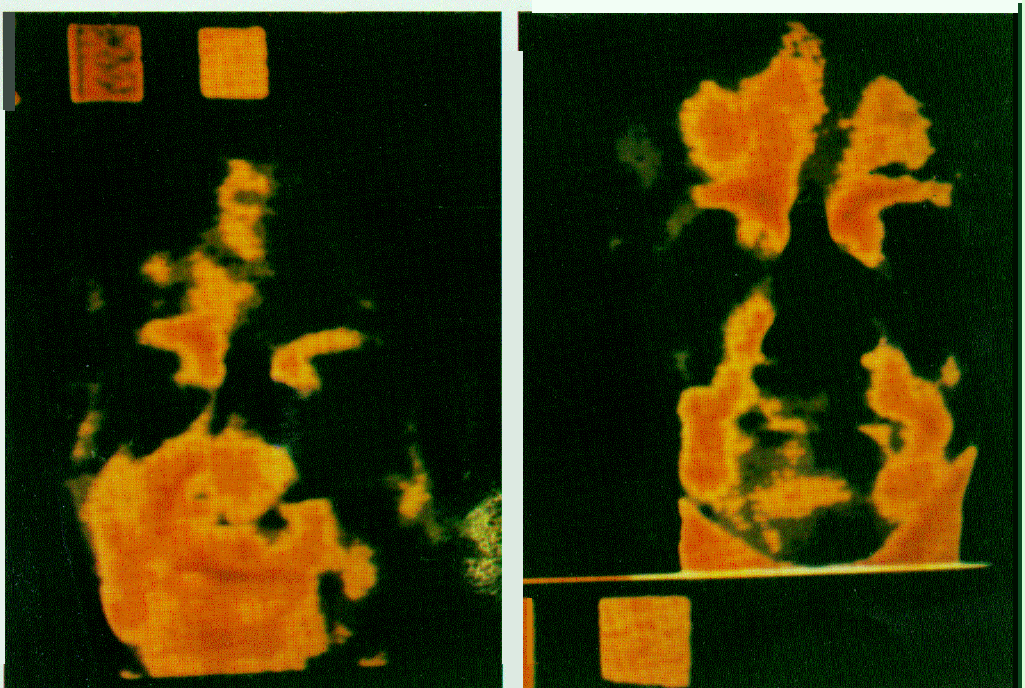


Fig. 4. Unilateral internal carotid artery obstruction before (A) and after surgery (B). Removal of obstruction produced increased heat in the previously cool forehead.

as radiculitis often produces coldness of the limb,

DISORDERS OF VESSELS OF THE HEAD AND NECK

Arterial obstruction of the internal carotid arteries gave a cold spot across the forehead on one or both sides in our series. The exact temperature pattern on the forehead depended upon the nature of the collateral circulation to the forehead. When a frontal or supraorbital artery is obstructed, this circulation may be through the external carotid and temporal arteries into the obstructed internal carotid. Another collateral vessel is from the external carotid artery across the angle of the jaw, and along the side of the nose to the branches of the internal carotid artery. Thus, the head patterns can vary considerably when internal carotid disease is present. Figure 4 shows an 85 year old male before and after removal of an obstructing internal and carotid lesion. A cold spot on the forehead was present before surgery; this was converted to a hot spot after successful surgery.

DISCUSSION

Thermography is, in many cases, a primary instrument for the discovery and subsequent following of the course of vascular disease. When evaluating the digits of the hands and feet, for example, individual arterial disorders can be revealed easily and quickly. The device is also of importance in studying certain cardiac disorders such as pericardial effusion, irritation caused by pacemakers, and delayed wound healing after chest surgery [5]. There are certain characteristic thermographic patterns of the limbs - e.g. the « proximal nodular » pattern of rheumatoid arthritis; the distal interphalangeal pattern of osteoarthritis; the « triangular » pattern of synovial membrane infection; the bilateral dicuse « rainbow » finger pattern of primary Raynaud's disease, acrocyanosis and functional vasoconstriction; and the « mottled » pattern of Buerger's disease. Thermography is the instrument of choice in following the course of disease such as healing of fractures, the resolution of thrombophlebitis and the improvement in circulation following medical or surgical treatment.

Dynamic thermography assists in the examination of the venous system, defining perforator veins in order to assist the surgeon in the removal of such veins.

Diffuse vascular patterns in the feet suggest microemboli from the aorta or a lesion higher up.

AV fistulae can be localized thermographically, and a Bresica-Cimino shunt can be evaluated as to its state of patency.

Pelvic thrombophlebitis or femoral vein thrombophlebitis can be demonstrated; this ability is important because of the relationship between thrombophlebitis and embolism.

REFERENCES

1. Kruger R. P., Winsor T., Winsor D,. Birsner J. W.: A quantitative approach to thermography. Proceedings of annual meeting of American Thermographic Society. 261-268, 1973.
2. Abernathy M.. Ronan T.. Winsor D. W.: The diagnosis of coarctation' of the aorta by infrared thermometry. *Am. Hf. J., 82,* 731-741, 1971.
3. Winsor T.: Editorial: Thermography of the chest. *Chest, 58, 452, 1970.*
4. Winsor T., Hyman C.: A Primer of Peripheral Vascular Disease. Philadelphia, Lea and Febiger, 1965.
5. Winsor T.: Vascular aspects of thermography. *J. Cardiovas. Surg.,* Torino, 12, 379-88, 1971.
6. Winsor T.: Thermography in health and disease. *Ariz. Med. J., 23, 445-558,* 1966.
7. Winsor T., Bendezu J., Prevotat N., Ricatte P., Japy C., Francois J.: Bescanon, Le *Presse Medicale. 632, 1969.*
8. Winsor T., Bendern J.: Thermography and peripheral circulation. *Am. N. Y. Acad. Su.,* i21; 281, 1965.
9. Cook E. D., Pilcher M. F.: Thermography in diagnosis of deep venous thrombosis. *Brit. Med. J., 2, 5232-5236,* 1973.
10. Lawson R. M., Wilodek C. D., Webster D. R.: Thermographic assessment of burns and frostbite. *Can. Med. Assoc. J., 85,* 1129, 1961.

11. **Chucker** F., **Fowler** R., **Montomiya** T.: Induced temperature transients in Raynaud's disease measured by thermography. *Angiology,* 22, 580-593, 1971.
12. **McLaughlin G.** A., **Rawsthorne** C. B.: Thermography in the diagnosis of occlusive vascular disease of the lower limb. *Brit. J. Surg.,* 60, 655-656, 1973.
13. Patil **K.** D., **Williams** J. R., **Williams K.** L.: Localization of incompetent perforating veins by thermography. *Brit. J. Surg., 56, 620,* 1969.
14. **Mladick** R.: Clinical evaluation of the use of thermography in determining the degree of burn injury. *Plastic Reconst. Surg., 38,* 512-318, 1966.
15. **Kliot D., Birnbaum** S.: Thermographic studies of wound healing. *Am. J. Obst. Gyn.,* 93, 515-521, 1961.

THE VINCENZO MUTO MEMORIAL
FIRST NATIONAL CONGRESS
OF THE ITALIAN SOCIETY OF THERMOGRAPHY

From the 18th to the 19th of May, 1976, the First National Congress of Italian Society of Thermography was held in Trieste, at the Adriatico Hotel, on the beautiful gulf at Grignano beach. President of the Congress was doctor L. Fogher, Head of the Tumour Center of Trieste. Doctor Fogher's perfect organization with the help of english and french thermographers, assured good working conditions for the 200 Congress members (most italian radiologists and oncologists). So Acta Thermographica believes advisable to publish the summaries of papers presented at the Congress.

Dr. FOGHER introduces the Congress at the Opening Cerimony.

VINCENZO MUTO, M.D.
1919-1976

Suddenly, before the Congress, a great loss struck the Italian Society of Thermography: one of the promoters of the Society, doctor Vincenzo Muto, died in his native town, Naples. Doctor V. Muto was Head of the Radiological Department of the National Institute for Cancer Diseases in Naples and he was interested particularly in thermography. The members of the Italian Society of Thermography were very grieved at the death, not only of an influential expert, but of a very humane friend. The Management Committee decided to honour Doctor Vincenzo Muto dedicating to his memory the 1" National Congress of the Italian Society of Thermography.

Opening lecture

J. M. SPITALIER and R. AMALRIC (Cancer Institute, Marseilles, France)

Thermography and strategy in oncology

Dynamic Tele-Thermography (DTT) represents the most recent advance, currently at our disposal, in the field of medical thermography. At its name indicate:

- it is a *non invasive method* of investigation picking up at a distance electromagnetic infra red emission from the tegument;
- it makes use of *high speed cameras* with quantic detector translating the infra red emission into black and white and color immages, in an instant manner, which may guide other investigative procedures.

A thtrmographic pioneer, R.N. Lawson (Montreal), demonstrated that the *breast carcinoma is a heat producing neoplasm,* and did so by means of intra tumoral temparature measurements (average 36.5” Celsius, arterial blood 34.3, venous blood 35.4). Ch. Gros (Strasbourg) had measured breast cancer thermogenesis and found a range of values between 0.015 and 0.075 Watt/cm^3. The rate of cancer growth is directly proportional to this thermogenesis. *Blood warms up at the tumor site.* A continuous thermal exange chain must be present between tumor and camera (Table I), which implies that:

- the tumor emits a thermal message,
- the thermal message is transmitted towards the tegument (reasonable depth of tumor, conducting intermediate tissues without excess of fat, veins draining towards superficial planes),
- the thermal message is reemitted outwards by the tegument in the form of infra red radiation (ulceration, crusts, phaneres, sudation may considerably decrease skin surface emissivity),
- the thermal message is picked up by the high speed camera which processes it and converts it into a visual image through controlled manipulations of position, sensitivity, definition, speed and isotherms.

Tab. I. **Cutaneous thermographic manifestations of tumours * .**

	Gradient	*Surface*
Depth	↘	
Volume	=	↗

* According to G. F.,Pistolesi and Al., the gradient of thermogenic subcutaneous tumour is: conversly proportional to its depth and directly proportional to its volume.

Objective parameters for the interpretation of thermograms include: pattern of cutaneous vascularisation, presence or absence of hot spots, circunscribed or diffuse pattern of hyperthermia, distorsions of the thermal profile of the organ under examination. Abnormalities suggesting breast neoplasm are listed in Table II.

Tab. II. **Thermographic abnormalities types of tumours *.**

	Suspicious types	*Malignant types*
Hypervascularization	Asymetric	Anarchic
Hot spot	< 2,5°C	$\geqslant$ 2,5°C
Global hyperthermia	2°C	> 2°C
Profile distorsion	Limited	Extended

* According to our analytic stage of thermograms studies.

Thermal increments of the abnormally hot areas are measured with reference to the temperature of the surrounding skin (A,), the symetric skin (A,), and/or a well known isothermal area (Ad: mid xiphoïd area, for instance.

Our initial experience of 1,000 consecutive cases of confirmed breast cancers determined our choice of 2.5°C as a significant thermal gradient (with many false positives below and many false negatives above).

We classifly thermograms in 5 categories of increasing diagnostic severity (Table III).

Equipped with such device, working on well defined parameters and strictly classified data, the

Tab. III. **Diagnostic categories of increasing severity *.**

THl =	normal thermogram
TH2 =	abnormal thermogram of a benign type
TH3 =	doubtful or suspicious thermogram (with one sign of suspicion)
TIH4 =	thermogram of a malignant type (with several suspicious signs and/or one malignant sign)
TH5 =	thermogram of a malignant type (with several malignant signs)

* According to our synthetic stage of thermograms studies.

oncologist has a new way to approach diagnosis, prognosis, and treatment of breast cancer.

A) DIAGNOSIS OF CLINICAL AND OCCULT NEOPLASMS

1) **Screening of breast cancer.** DTT has been used for mass screening for breast carcinoma - D. Melander (Stockholm): L. Rocchi (Cesena) -. From 1968 to 1972, 6 authors screened 26,653 women with a total yield of 186 carcinomas, i.e. 7‰; 27% of which at a preclinical stage. DTT is a very fast method in mass screening - W. B. Hobbins (Wisconsin) -. By similar means, Ph. Strax's yield in New York is 14‰.

Added to other diagnostic methods, DTT narrows the gap between diagnostic and treatment of breast cancer; it has significantly improved, we think the quality and utility of diagnosis in the patients who have come to us sometimes for' simple breast pains.

Out of 1,878 first breast cancers seen with DTT between June 1970 and December 1975, thermography detected 19 non palpable neoplasms (1%) and 169 neoplasms with clinical and/or radiological benign appearances (9%).

We screen systematically the opposite breast following treatment of the side involved and after. In this manner, we have observed opposite side involvement in 3.5% of the cases 10% of which occult) at the time of the primary treatment and in 6,5% of the cases (15% of which occult) in the 3 years following treatment.

These data demonstrate the role of DTT in detecting occult lesions of the other breast. In such cases DTT gives direction for further classical investigations.

2) Early diagnosis of other malignancies. a) *Small size breast cancer:* out of 1,165 breast carcinoms 5 cm or less in diameter (Tl and T2 categories in UICC classification) 148 had normal or benign type thermograms, amounting 13% falses negatives. DTT fails to pick up l/3 of carcinomas measuring less than 2 cm in diameter, indicating the necessity of a combined approach (P.E., radiography, needle biopsy,. . .) for the identification of small breast cancer.

b) *Malignant melanomas of the skin and eye:* angiomas and malignant melanomas are the most heat producing tumors of the skin, with 8/10 positives on a series of 77 cases of primary malignant melanomas. When the diagnosis of a skin naevus is questionable, DTT may enlighten the physician as to the real nature of the lesion and appropriate therapeutic approach.

c) Uterine cervix carcinomas and dysplasias: DTT on mucosae surfaces shows that even small cervical carcinoma produce heat: 2 carcinomas in situ were in that way. The severity of dysplasias seems to correlate with their thermal emission in a series of 90 cases. DTT seems to have a place in the combined approach and follow up of epithelial lesions of the uterine cervix in high risk women.

d) *Primary malignant tumors of bone and soft tissues:* where good thermal connections exist between skin and bone, DTT can be used to detect primary malignant bone tumors. It offers practical advantages in children and can be easely repeated. In cases of bone pains, without X ray evidence of tumor, DTT may provide a convenient way to watch a lesion and guide further appropriate studies.

B) STAGING

Here again the use of DTT in breast cancer can be extended to other types of tumors.

1) **Local extension.** Most of the time, thermal disease extends beyond the clinically and radiologically evident disease. DTT may draw the physicians's attention to some peripheral parts of the main lesions where he will palpate subcutaneous invasion. The surgeon will also look for secondary disease suggested by DTT in the operative specimens, as we have seen in breast carcinomas, malignant melanomas and sarcomas.

2) Multifocal disease. 40% of adenocarcinomas of the breast present with several hot spots on thermograms, and there are similar findings in primary tumors of bone, soft tissues, thyroid.

3) **Nodal involvement.** Fat surrounding regional lymph nodes interfers with thermography, with great value of positive images. DTT is moderated helpful in axillary and neck lesions, but will indicate distant cutaneous lymphatic permeations, such as in transit metastases of malignant melanomas of the limbs, some of which are palpable and some not.

4) Bilaterality. Apparently unilateral involvement of paired organs requires full examination of the controlateral organ, at high risk demonstrated by the cancerization of the first side. In patients with breast cancer we know the radiological, thermal and clinical birth date of the controlateral lesion, with an average 18 months lay between radio-thermal and clinical abnormalities.

5) Distant metastases. Skin, subcutaneous metastases as well as deeply seated ones, when their thermal message is able to reach the skin surface, can be located by **DTT.** In spite of its depth, vertebral body involvement is demonstrable, mainly through the spinous processes adjacent to skin surface, live bone being a good thermal conductor. We suggest that *initial examination and follow up* include *rachis and total body thermography.*

DTT has a role in the diagnosis and staging of many neoplasia despite 5 to 30% of false negatives and 10 to 20% of false positives, because it brings up original data. However it must be used concomitantly with other classical investigating methods.

C) ASSESSMENT OF BIOLOGICAL BEHAVIOUR OF CANCER

The severity of a cancer is related to its rate of growth more than its size at the time of diagnosis and treatment. An old large slow growing tumor is by far less threatening than a recently appeared fast growing smaller one. Assuming that heat production of a neoplasm parallels its growth rate, one may use **DTT** as a *speed tele measure for some cancers,* and as a prognosis parameter.

1) Fast growing breast cancers. 10 to 20% show indication of rapid growth such as oedema, inflammation of skin or evident acute carcinomatous mastitis. They show typical thermograms with gradients higher than average and abnormaly extended thermal disease. Sometimes DTT solitarely gives the alarm.

Table IV represents 4 thermovisual patterns of breast cancers evolutive phases. The cases have a significantly worse prognosis. In our current study the ratio of *failure in the* 3 *years following curative treatments for operable breast carcinomas* correlates with the gradients:

for $\Delta \geq 4°C$: 19/25 = 76%
for $\Delta \leq 2°C$: 4/20 = 20%
(with $p=0.001$)

2) Slow growing breast cancers. DTT false negative confirmed breast cancer relates to deep location, small volume, over lying fat, non emissive over lying skin, or (as in 5% of our 1,878 cases) decreasde thermogenesis with slow rate of growth. Longer follow up will inform us on the signification of such findings. None of them have show lethal generalization after up to 6 years of observation.

3) Scirrhous forms with late acceleration. l/3 of reputedly slow growing scirrhous breast cancers is in evolutive phase by DDT. Patients often become after a change in the behaviour of their up to then resting disease and present with hotter thermograms. Those thermographic flare up may account for the disappointing treatment of some of those scirrhous, the easy going reputation of which should be reconsidered. Here again, DTT is useful in revealing a change in the biological behaviour of **some** neoplasms.

4) Malignant melanomas of the skin. Two patterns of DTT can be encountered: well circumscribed hot spot, corresponding to palpable tumor, on one hand; on the other, hot areas extending proximally beyond the clinical disease, creating a centripetal lengthened ellipse, the « *flame sign »:* these are regulfarly associated with 100% mortality within 1 year.

Prognosis cancer may be made easier by DTT: higher thermal rise, extends of thermal abnormality beyond clinically recognizable disease, centripetal flame, all of those suggest a guarded prognosis. In a more theorical field, insights into the biological energy of cancers.

D) THERAPEUTIC DEDUCTIONS

DTT may help the physician to decide upon the appropriate therapeutic modalities and to assess their results.

1) Choice of therapeutic modalities. Radiotherapy and surgery depend much, in their practical realisation, upon the traditions of each oncological school. However thermograms should be taken into account in defining fields of irradiation and areas to be resected.

We have chosen to do so, aware of the insufficiencies of thermography used alone, but believing that it points out to significant pathologic

Tab. **IV. Categories of growth rate of breast cancers ***

PEV 0 = gradient 5°C	+ hot area $\leq$ 2 quadrants
PEV 1 = gradient 5°C	
PEV 2 = gradient 4°C	+ 2 quadrants < hot area < 4 quadrants
PEV 3 = gradient 3°C	+hot area $\geq$ 4 quadrants

*** According to our thermo-clinical studies. PEV 0: possible slow** growing cancer. PEV 1, 2 and 3: fast growing cancers.

changes. *We draw the +2°C isotherm under thermoscopy* where it exists on the tegument overlying breast cancer, malignancies of skin, soft tissues, bone, nodes. This area is included in the irradiation and resection fields and is often added in the classical planings.

The results of this *thermovisual definition of targets* will be analized in due course, but we already believe in a lower rate of local recurrence following radiotherapy, more specifically with electron beam, when this approach is used.

It also helps the surgeon resecting areas of secondary X rays injuries and plays a role in reconstructive surgery by marking out vascular pedicules, in drawing and transplanting flaps, in following up grafts.

2) Choice of therapeutic strategy. Radiotherapy, resections, lymphadenectomy require technical perfection for success. Success also demands a proper chronology of the modalities used for treatment. DTT may help to choosing the modality of primary treatment: a large cold cancer may be operated initially, a smaller hot ont may do better following primary radiotherapy. In fact we suggest that chemotherapy and/or radiotherapy be used whenever clinical or thermal evidence of rapid growth exists.

3) **Follow** up. Following curative treatment, DTT may be performed at regular intervals for detecting recurrence and metastatic disease as well as new neoplasms.

Following curative radiotherapy with conservative aims of operable breast cancers, DTT shows a thermal tide withdrawing slowly (18 months and over), with 70% cooled down at 3 years. Failure correlates with persistance of the abnormal patterns or flare up after improvment. Radiotherapic breast presents with a moderatly and persistantly stable abnormal medium patterns.

DTT will also help in assessoring the effects of chemotherapeutic and endocrine management of cancers, providing objective data of response.

*

We shall admit in conclusion to the failure of thermography to detect deep seated malignancies (such as respiratory and digestive tracts). We remain however convinced of its indication in the diagnosis, prognosis, therapuetic management and follow up of many cancers.

We are particularly conscious of the value of DTT in basic research on the behaviour of malignant neoplasms, with original data at clinician disposal. *It seems to us that the concept of energy production by cancers brings in a new dimension to the whole conception of malignant disease.*

1st Round Table: *Thermography in extra-mammary tumours*

Moderator: A. TOTI (Ferrara, Italy)

INTRODUCTION

The thrust of this Round Table was to discuss the value and limitations of thermography in extra-mammary tumours. Specialists in various fields presented not only their own work but that of other colleagues in Italy. The following sectors were represented: thyroid, bone, orbit, lymph nodes, skin and salivary glands thermography. At this time, there are a great number of dispersed thermography case studies which need not only be interpreted, but organized into an easily understood, reliable diagnostic discipline. There is no doubt that thermography is an extremely objective, instrumental diagnostic procedure, but there is still space for technical improvements, and with these advances we should realize our goal.

A. GHISOLFI (Pavia, Italy)

The thermographic investigation of vascular, inflammatory, and neoplastic lesions of the orbit

In our Ophtalmic Clinic we have made use of telethermovision for more than 2 years and have performed more than one thousand examinations on patients complaining of ophtalmologic disturbances. It is the specific purpose of this report to give our results obtained in the orbital pathology of inflammatory, pseudo-inflammatory, vascular and neoplastic nature. Examining the characteristics of the normal orbit, it is useful to recall that hyperthermia is always accentuated medially and in the upper-internal angle either due to the course of the angular vessels or because these are the deepest zones and therefore much less ventilated. Hyperthermic areas are also individualized in the most external side of the orbit, the superciliary region, the superior and inferior orbit, and the nasion. The thermogram of the face may be modified by all of the various pathologies of the orbit since its contents, being external with respect to the osseous structures, radiates its thermic activity towards the cutaneous area, and so it is possible to make an evaluation that is impossible for the other endocranial structures. From a thermographic point of view, we classify the exophthalmias as follows: a) *Accentuated kypertkermia* (the rise in temperature must always exceed 4°C): we include in this group exophthalmias which are secondary to inflammatory processes, tumours and vascular anomalies and malignant richly vascularized neoplasms. b) *Hypertkermia* (the rise in temperature varies from 2 to 4°C): we consider in this group those which are secondary to inflammatory pseudo-tumours or modestly vascularized neoplasms. *c) Hypothermia* in which we include the exophthalmias secondary to endocrinopathies, benign tumours such as lipoma, osteoma, neourofibroma, dermoid cysts. Considering our study, we believe we have good reason to state that thermography is a very effective help in the diagnostic research of diseases of the orbit being a very inoffensive and easy examination. Thermography should be performed before the traditional tests such as carotidography, orbital phlebography, scintigraphy, ecography, Emi-scanner, etc.

L. ACCIARRI (Verona, Italy)

Thermography of parotid tumours

The thermographic pattern of the parotid region under normal conditions is characterized by temperature values that are either tendentially or decidedly hot. The hot parotid zone is delimited in front, above, and behind by the cold zones of the cheek, the ear, and the hair respectively. It continues downwards into an almost constantly hot band that corresponds to the external jugular vein. Normal anatomical variations of the region lead to a variety of thermographic patterns but all within rather definite limits. Numerous pathological conditions can modify the thermographic appearance of the parotid region, either by an increase or decrease in its temperature. Space occupying lesions of the parotid gland are characterized by thermograms that vary in relation to the malignancy or non-malignancy of the tumour. a) Benign space occupying lesions (cysts, lipomas, etc.), at sialography, present narrowing or displacement of ducts without structural involvement. Thermographically, when they are small they do not modify the metabolism or displace the vessels enough to modify the normal thermogram. When they are larger, however, they present a pattern of more or less marked hypothermia in relation to the extension of non functioning parenchyma. b) Mixed tumours of the parotid gland always present a pattern of slight hyperthermia, with a thermic gradient between 1 and 2°C. c) The most elevated hyperthermias, with a thermic gradient greater than 2°C in comparison with the healthy side, are seen with malignant tumours and are related to the marked metabolic and vascular disarrangement. Sialography shows the irregularity of the parotid ducts. Problems of differential diagnosis arise from inflammatory processes of the salivary glands: acute forms are always hyperthermic. Chronic forms give variable patterns usually with normal or cool temperatures. Collagen diseases in the inflammatory phase yield hot temperature patterns. In the scleroatrophic phase however they appear markedly hypothermic. Thus with space occupying lesions thermography can furnish information for differential diagnosis while sialography shows only a nonspecific empty area in the glandular parenchyma. Infact, benign forms are cold, mixed tumours are hot, and malignancies present the hotest values in the space occupying lesions. This last finding may be very useful in deciding on surgical treatment.

G. VIGANOTTI (Milan, Italy)

Tumours of the thyroid

At this time the diagnosis of thyroid malignancy is often questionable, especially with regard to nodules with low or absent I^{131} uptake (clinically doubtful). In order to establish better diagnostic criteria the National Tumour Institute of Milan, in collaboration with other institutions (Radiology Institute of the University of Ferrara) is carring out thermographic evaluation of all cool

Tab. I. Histologically controlled cases of National Tumour Institute, Milan.

Disease	*Number of cases*
Malignant tumours.	22
Benign tumours	105
Thyroiditis	2
Hodgkin	1
T. B.	1

thyroid nodules. The examinations have been performed in air-conditioned, thermostatic environments (20°C and 50% relative humidity) with the

Tab. II. **Thermographic patterns in benign tumours.**

Tkermographic patterns	*Number* of cases
Hypothermic	4 (3.8%)
Normothermic	25 (23.8%)
Hyperthermic 0.5-1.4°C	54 (51.5%)
Hyperthermic 1.5-2°C	22 (20.9%)
Total	105 (100%)

patient located at the shortest possible distance from the thermograph. Pictures were taken in black and white, and color, for the most accurate possible determination of the thermic gradient. The thermographic positivity has been evaluated at 1.5°C for the cases studied with the Aga Thermograph and 2°C for those studied with thermograph Barnes M. I. B. model. In Table I the cases subjected to thermography at N. T. I. of Milan are reported. These cases were also histologically controlled. Table II, which concerns benign forms, points out a high false positive rate. Table III (malignant tumours) demonstrates that the number of cool or hypothermic tumours is relatively low.

Hodgkin's and T. B. localization have been found to be normothermic. Thvroiditis has a thermic gradient between 1.5°C and 2°C. In three cases laterocervical metastases have resulted hyperthermic. The results of the Radiology Institute of Fcrrara University are reported in table IV.

Prom the above data we may make some considerations. Thermography presents a high rate of diagnostic accuracy in malignancy, but also a high rate of false positives. Occasionally, in our experience, it has been the only method which enable us to suspect a malignancy. If these data will be supported by wider surveys, thermography may become a popular diagnostic method in thyroid pathology; however, one to its built-in limitations, it must be associated with the clinical examination and radioisotopic techniques.

Tab. III. **Tbermographic patterns in malignant tumours.**

Thermographic patterns	*Number* of cases
Normothermic	2 (9.1%)
Hyperthermic 0.5-1.5°C	2 (9.1%)
Hyperthermic > 1.5°C	18 (81.8%)
Total	22 (100%)

Tab. IV. **Correlation between clinico-pathologic and thermographic data of 36 nodular lesions of thyroid (Institute of Radiology, University of Ferrara).**

Clinico-pathologic diagnosis	*Number* of *cases*	*Tkermographic patterns*	
		normal	*abnormul (>2°C)*
Benign nodule	16	14	2
TSH non-dependent nodule	3	—	3
Malignant nodules	7	3	4
Multiple nodules	7	6	1
Acute thyroiditis	2	—	2
Other pathologies	1	1	—
Total	36	24	12

S. D. BIANCHI (Torino, Italy)

The value of thermography in the investigation of lymphoma

Damage to superficial lymph nodes is often one of the earliest clinical signs of lymphoma and skin sites are by no means rare. « Surface » manifestations of this kind are obvious candidates for thermographic investigation. In addition, there is probably a similarity between the metabolism of lymphomatous tissues and that of frankly neoplastic processes, where the typical alteration of cell metabolism is the cause of hyperthermia and opens the way to thermographic detection. These considerations, therefore, suggested that thermography might reasonably offer a rapid and, above all, non-invasive method of establishing an early and sufficiently reliable differential diagnosis in cases where the only clinical sign is a superficial adenopathy. 15 patients with Hodgkin's disease and 13 with other forms of lymphoma were examined with an Aga Thermovision 680. The axillary and inguinal nodes have not been much used due to « masking » and hence false results owing to the presence of hair. On the other hand, complication of the thermographic picture on the part of large hyperthermic vessels in the vicinity has made interpretation difficult in the case of supraclavicular and laterocervical sites. Our findings in this small series make it clear that lymphomatous tissues are hyperthermic. In some cases, comparison between the subsequent course of the clinical and thermographic pictures suggested that a relationship might be discernible between temperature changes, the treatment modality, and, possibly, the clinical stage. Hyperthermia cannot yet be classed as a sufficiently reliable parameter for the diagnosis of lymphoma, though it can usefully be employed to monitor the ongoing picture and the effect of treatment, particularly radiation therapy. For example, the failure of a site to cool after such treatment, once a reasonable time during which hyperthermia caused by inflammation may be expected to have relapsed, can be seen as a sign of reactivation of the site. It is this feature of thermography that points to its utility in day - to - day practice for the surveillance of lymphomas. Its absolute innocuousness and relatively simple technical requirements render it both a quick and manageable form of examination that can be repeated indefinitely. Were the results of research on a wider scale to show that other elements of semeiological value are present in thermographic findings, the examination would prove a useful adjunct to the instrumental methods of diagnosis already known.

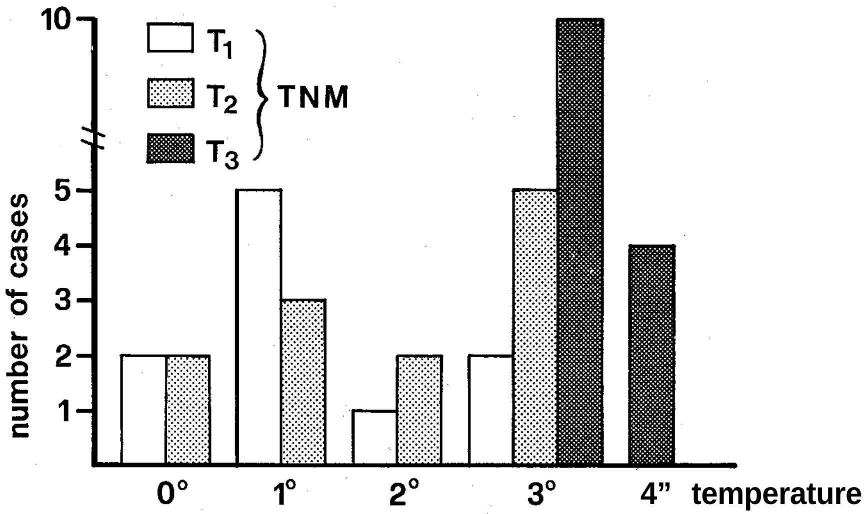
M. CRISTOFOLINI (Trento, Italy)

Diagnostic value of thermography in the differential diagnosis of malignant melanomas

The purpose of this work is to verify the validity of thermography in the differential diagnosis of primary cutaneous melanomas, nevi, and pigmental cutaneous carcinomas. Hypothetically it should be possible to correlate thermographic data with the morphologic and/or clinical characteristics of skin neoplasias in order to determine not only the type but also the biological beha-

Tab. I. **Diagnostic value of thermography.**

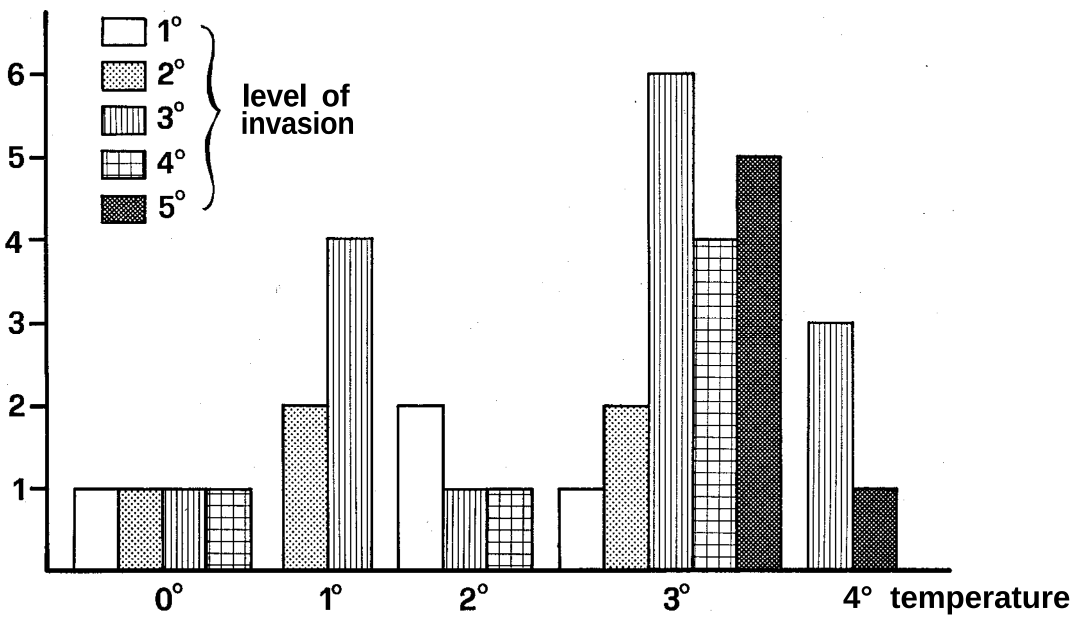
Type of tumour	*Number of cases*	*Thermographic patterns*	
		Hypo- and normothermic	*Hypcrthermic*
Skin tumours, not nevi, simulating melanomas	67	**56**	**11**
Pyogcnic granulomas	*10*	**4**	**6**
Seborroic warts	**7**	**7**	-
Angiokeratomas	**2**	**2**	-
Thrombosed capillary haemangiomas	**5**	**5**	-
Dermatofibromas	**20**	**18**	**2**
Pigmented basal cell tumours	**23**	**20**	**3**
Nevi	**148**	**137**	**11**
Primary malignant melanomas	**36**	**4**	**32**



Graph 1. Prognostic value of thermography.

viour of the tumours. Consequently thermograms would not only be « diagnostically » significant, but also « dynamically » significant because they would document the level of infiltration, or diffusion and the presence of a relapse or of metastases and thus they would be able to guide the therapy according to the evolution of the tumour.

The thermograms were performed with a Bofors IR Mark 3. 148 nevi, 36 primary cutaneous malignant melanomas, 47 melanoma metastases and 67 cutaneous neoplasias (10 pyogenic granulomas, 7 seborroic warts, 2 angiokeratomas, 5 thrombosed capillary haemangiomas, 20 dermatofibromas, 23 basal-cell tumours) were examined. Due to the



Graph 2. Thermography as a guide in therapy. Hyperthermia correlates best with the level of invasion of the melanoma. When it goes beyond the third level not only excision of the neoplasia but also of the regional lymphnodes become necessary.

pigmentation and/or the clinical aspect, the differential diagnosis with melanoma was problematic. The thermographic data of these growths were compared with certain clinical and morphologic characteristics in order to note any correlations. The sites of the 71 melanoma operations were repeatedly examined by thermography to demonstrate any possible recurrence. Primary malignant cutaneous melanomas are mostly hyperthermic (88.9%), while nevi are almost always hypothermic (92.5%), unless complicated by folliculitis underneath, in which case they are « hot ». The remaining cutaneous neoplasias which can simulate melanoma (seborroic wart, basal cell tumour, dermatofibroma, angiokeratoma, thrombosed haemangioma) are cold or isothermic. Due to these facts thermography assumes a determinant rôle in the differentiation of malignant melanoma from nevi, and from the remaining cutaneous neoplasias. This is the « *diagnostic value* » of thermography (Table I). « *Prognostic* value » of thermography: the hyperthermia of malignant melanoma seems to correlate with the clinical classification according to TMN, which is a direct expression of the clinical character and therefore the prognosis of the tumour (Graph *1*). *Thermography as a guide in therapy :* since the clinical state (TNM) is also determined by the degree of infiltration, thermography can be a guide to regional nodal spread requiring, therefore, the extending of the surgical excision (Graph *2*). *Thermographic control of melanoma evolution:* thermography permits the observation of the biological conduct of the melanoma both in the case of recurrences after excision and in the lymphonode, and cutaneous metastases which are usually hyperthermic. The sites of previous excision of malignant melanoma are initially usually hyperthermic. Later they appear cold. They stay hot only if a recurrence of the tumour is present (Table II A). In metastases to lymph nodes the hyperthermia is proportional to the extension of the proliferation. Cold thermograms correspond to very small metastases with limited involvment of the lymph node tissue (Table II B).

Tab. II A. **Thermographic control of melanoma evolution. Follow-up thermography at the site of previous melanoma excision.**

Period of time	*Number of cases*	*Thermographic patterns*	
		Hypo- and normothermic	*Hyperthermic*
< 1 year	10	2	2
> 1 year	11	9	2

Tab. II B. **Thermography of malignant melanoma metastases.**

Site of the metastases	*Number of cases*	*Thermographic patterns*	
		Hypo- and normothermic	*Hyperthermic*
Skin	33	4	29
Lymph nodes	14	4	10
Total	47	8	39

A. GRISOTTI (Milan, Italy)

Non-melanotic cutaneous tumours

Telethermography in the case of cutaneous epitheliomas is equivocal rather than distinctly differentiating them from melanomas which are in the great majority of cases hyperthermic. Basal cell carcinoma is generally hypo- or isothermic and only rarely presents a slight increase in temperature with respect to the adjacent zones.

Thermography has great diagnostic value in differentiating between pigmented basal cell tumours, which are « cold », and melanomas which present hyperthermic, flame type phenomena. Spinocellular epitheliomas are also generally hypothermic especially if they are ulcerated. At times, however, they can present a hyperthermic halo which is an expression of peritumoral infiltration - notably in diffuse and invasive forms. Certain rapid growing spinocellular epitheliomas with precocious local and regional nodal invasion give frequent « hot » thermographic responses. This differentiates them from the majority of cases. Since the increased production of heat in malignant tumours is closely connected to the metabolic activity of the neoplastic cell, thermography represents a simple innocuous and worth-while means of cellular grading and prognosis. Lastly, it is important to underline the value of thermography in the follow-up of epitheliomas after surgery or radiological therapy.

N. CELLINI (Roma, Italy)

Skelatal tumours

After more than ten years since its first employ ment (Gershon-Cohen 1965), the rôle of thermography, in the study of primary and secondary skelatal neoplasms is not at all established. It is certain that bone is one of the best conductors of infrared radiation and that its depth, compared with the cutaneous surface, does not compromise the emission capacity (Melki 1973). Nevertheless, in 1973, Dr. Lamarque's group (Montpellier) affirmed that, in his experience, thermography does not substantially add any new element compared with traditional radiology. On this matter, our cases include mainly bone lesions following mammary carcinoma, and I do thank Dr. G. Viganotti (Tumors Center Milan) for having provided me with the results of his experiences concerning infantile and youthful primary bone neoplasms. Precocious diagnosis of primary and secondary bone tumours, as in other kinds of neoplasms, is still difficult, and therefore, close co-operation among radiologist, specialist in nuclear medicine and histopathologist is considered necessary by all. As far as therapy is concerned, especially if surgical or radiant, it is extremely important to be able to define carefully the actual dimension of the neoplasm. Lastly, any method permitting monitoring of the tumour's evolution, once treatment has been carried out, is particularly useful. Regarding these three aims, the direct or contrastographic radiographic investigation presents, due to its own nature, some limitations while bone scintigraphy, even if it allows a metabolic and therefore dynamic control of neoplasm, has its limitations in its undetailed description, which makes a differential diagnosis difficult. The results obtained by thermographic investigation, are not very different from the radioisotopic ones, even if, for instance, some Authors assert the possibility of a thermographic differential diagnosis among primary, malignant and benign bone tumours. Malignant tumours would have a thermic gradient of at least 4°C and a characteristic pathological circulation while in benign bone tumours the thermic gradient would not exceed 2°C and there would not be a pathological circulation. Between primary malignant tumours and singular bone metastases one may note that the pathological hyperthermy would not exceed 2,5°C in the later. The problem of the « characteristic » thermic gradient (4°C, 2°C) and the percentage of controlled, positive histological diagnoses is still rather controversial. With this in mind, the group of the colleagues of the Tumours Institute of Milan, tend to check thermographic reliability comparing the extension of the hyperthermic area with the dimensions of the tumours established by other methods. They are also trying to determine if thermography is useful for therapeutical programming and control of patients who underwent chemoradiotherapy. Thus far eighteen cases of limb tumour in young people between 6 and 19 years, have been studied. This type of case gives a relatively better possibility of determination. In all cases, a very high hyperthermic degree was observed (only in one case, the gradient was+ 1°C) indipendent of the tumour's dimensions. Generally, the hyperthermic area (focus and pathologic circulation) was more expanded than the radiographic determination. In three cases, a control was carried out some time after radiochemotherapy and negativization of the thermo graphic table, in accordance with metastases the radiological and clinical diagnosis, was observed. As far as bone metastases are concerned, especially the osteolitic ones, it is well known that radiological positivization is observed only when more than 50% of the calcium has been removed (Babaiantz 1974). Intertrabecular metastases only cause displacement of the medula without modifying the calcificated bone tissue (Schinz). Many Authors, both in Italy (Lovisatti) and abroad (Melander, Amalric, Melki) have tried to analyze the possibilities and advantages offered by thermography, alone or associated to scintigraphy usually with Technetium phosphate. According to the experience of these authors, with whom we agree, pathological hyperthermy is generally not very intense (0.5-2.5 degrees), yet, the opinions on thermography employement, in this field, are very discordant. In 1969, Lovisatti did not find any case of exact diagnosis in 17 patients studied. In 1972, Amalric, in 90 cases studied, reported 85% positivity. Last by, in 1973, Melki, on 92 patients, spoke of 74% exact diagnosis by thermography alone, that rose to 97% associating thermography to scintigraphy. This last result seems to show the way for the employement of this method. Its greatest merit is its easiness of execution and repetition, even if, unfortunately, just like scintigraphy, it is not able to give a « characteristic » diagnosis. In conclusion, we believe that thermography has great value both in the follow up of primitive and metastatic bone tumours, and in the precocious, preradiologic diagnosis of metastasis. Even if thermography is not absolutely specific, like scintigraphy it is a particularly easy and economic procedure in this field.

A. TOTI (Ferrara, Italy)

Closing remarks

The point of this Round Table is to emphasize that the application of thermography is continually expanding, confirming its interdisciplinary nature. It is also notable now that the more significant results are obtained in skin tumours. This is due to the fact that melanotic tumours are hyperthermic while epithelial tumours are more or less hypothermic. Hopefully, technological progress will give us more precise instruments in the near future which will give better definition and an increased thermic discrimination even for deep lesions. It is necessary to underline the fact that many tumours escape thermographic diagnosis (false negatives). In spite of this, thermography is capable of demonstrating tumours where all of the other methods have failed, particularly in bones. This permits a precocious, prognostic grading, even before a histologic study, as in lymphomas, and thyroid and parathyroid tumours. One must therefore consider both the qualitative and quantitative data together. The problem that now emerges, is that of standardization. All of the thecnical and methodologic parameters must be organized to a very high degree so as to allow, for example, the construction of maps with precise numerical indications of the various levels of temperature emission, not only superficially but from the deeper levels. Standardization will permit reproductability and therefore greater possibility for early and effective therapy. It must be underlined that thermography might concentrate even more on the principles of complementarity, multidisciplinarity and universality (Gautherie, Cohen, et al.). Perhaps only in a small part we forced ourselves to remain faithful to these principles, trying to speak a common language. At least in this way, every « rapporteur » forced himself to use clear and concise language, stimulating the critical enthusiasm of all, and including the greatest possible number of participants in this interdisciplinary work. Much time, and much work awaits us in our attempt to better the diagnostic and prognostic value of thermography. But the results will be worth the battle because it will tend to bring medicine from the present state of art to that of science.

IInd Round Table: *Thermography in breast tumours*

Moderator: C. VALDACNI (Trento, Italy)

INTRODUCTION

The agreement, during the preparation of this Congress, was to ask, through a questionaire, to foreign Institutes and Colleagues, that use thermography as a screening method, their data and their opinion on the rôle of thermography in a survey for breast cancer detection. Indeed, the opinions we find in current literature, do not agree on the value we should give to thermography as an instrument for early diagnosis. Of the twenty or more questionaires we sent, we received only a few answers (about one third, see table I). The result is quite modest; however,

Tab. I.

Name and Institute	Method of screening: Clinical exam	thermo-graphy	mammo-graphy	others	Age groups	Number of unse-lected (annualy)	% of women as being at risk	% of women with clinical symptoms
Greening W. P. Royal Marsden Hospital London (England)	yes	yes	yes	—	20-75 years	8,000	50	30
Strax P. Guttman Institute New York (U.S.A.)	yes	yes	yes	yes	—	50,000	-	20
Isard H. J. The Albert Einstein Medical Center Philadelphia (U.S.A.)	yes	yes	yes	—	—	10,055	-	56.31
Ghys Ii. Laboratoire Radio Medical Montreal (Canada)	yes	yes	yes	-	-	-.	-	57
Stark A. M. Queen Elizabeth Hospital Gateshead (England)	yes	yes	yes	-		-		
Lapayowker M. S. Health Sciences Center Philadelphia (U.S.A.)	-	yes	-	-	35-75 years	5,000	-	-
Jakobsson S. Karolinska Sjukhuset Stockholm (Sweden)	yes	yes	yes	-	35-75 years	8,167	-	-

it will help us to examine and interpret this problem more precisely, just the same. Personally I think that: 1) the role of thermography as a mass screening method is not well defined in many centers, around the world. Probably, this generates a certain uneasiness in aswering our questionaire and may also be one of the main reasons why we did not receive replies to all the questionaires we sent. 2) The answers we received seem to « support » point 1) and in a certain way justify it because the data given to us by Ghys, Strax, Isard, Lapayowker, Jakobsson, and Stark, whom I thank very much for their courtesy, are discordant. For the same reason we can not draw a well defined conclusion from these data. Current literature, as I have already mentioned, and the papers presented at the recent International Congress on Prevention and Detection of Cancer held in New York (April 27th, 1976) seem to give further support to this idea. A work on this subject will soon be published in « Acta Thermographica ». From a panoramic review of these opinions and data we may say that almost all the authors (with the exception of the french group) give to thermography a secondary role in early breast cancer detection, whereas, mainly in the IJ.S.A., mammography is the most important test in the physician's hands. For some time, I was also of this opinion. The high number of false positives means that thermography is uncertain and absolutely non-specific. In our histories, for example, among 15,000 examined women, 4,905 of them had abnormal thermograms which means about one third of the entire population examined! For this reason, after a few years when we had introduced this method in our Tumour Center, I was personally oriented in considering it, may be quite superficially, valid mainly because it was accepted quite favourably by the women and it was also a more effective psycologycal tool in recalling the female population to our Center than the simple anamnestic or clinical exam. Now, after almost eight years of thermographic practice, I reexamined our results with the greatest care, specially from a statistical point of view. My conclusion is that we are now in the position of defining more precisely the role of thermography in a breast cancer screening. In my opinion this

Women with clinical symptoms			*Women without clinical symptoms*			*Cases without follow-up*	*Th+ %*	*Th− %*	*False positive %*	*False negative %*	*Notes*
abnormal Th %	*equivocal Th %*	*normal Th %*	*abnormal Th %*	*equivocal Th %*	*normal Th %*						
9	14	77	6	12	82	1/3	-	-	-	-	-
60	-	40	20	-	80	-	-	-	-	-	-
36	-	64	23	-	77	-	30.31	69.68	27.5	28.75	accuracy 75%
—	—	—	—	—	—	—	—	-	0.3	4.5	-
-	-	-	-	-	-	-	-	-	13.6	21	-
-	-	-	-	-	-	-	16	84	2.25	0.14	-
-	-	-	-	-	-	-	-	-	-	-	-

definition passes through an exact evaluation of the type of information thermography may give us. The knowledge of the precise questions to put will make us understand what we may and may not expect. At this moment, in Italy, there are a few centers sufficiently experienced in Milan, Cesena, Busto Arsizio and Trento. To the speakers, chosen among these centers, we will now ask their opinion on the rôle thermography plays in a breast cancer screening.

B. PERANI (Trento, Italy)

1) In our screening center we use thermography not as a « stand-alone » exam but integrated with other exams: history for risk evaluation, clinical exam, mammography, cythological exam, and eventually biopsy.

2) The women who come to our center are: a) spontaneous arrivals or b) sent by physicians who already have suspected a pathological breast situation. We consider very carefully the risk factor. Among 17,000 women we visited, 6,230 of them were subject to high risk (36.6%); and 128 of these had cancer (2.05% of 6,230). This is 56.14% of all the 228 cancers we found. Among the women that did not present any particular risk factor, 10,770 (63.4%) we found 100 cancers (0.93% of this group and 43.85% of all the cancers). The women that have only the anamnestic exam positive and all the others negative are visited every 6 months. The women subject to high risk with a normal thermogram and positive clinic, or with an abnormal thermogram and a negative clinical exam are sent to mammography and eventually to other exams.

3) Comparative results.

a) Thermography

false positives = 5,901 (34.7% on the 17,000 patients)
false negatives = 34 (14.9% on the 228 cancers)

b) Clinical exam

false positive = 3,339 (19.6% on the 17,000 patients)
false negative = 38 (16.6% on the 228 cancers). The women sent to mammography after the evaluation of the three preceeding exams (thermography, family history, and clinical exam) were 6,590.

c) Mammography

false positive = 3 (0.04% on the 6,590 patients)
false negatives = 7 (3.1% on the 288 cancers). The follow-ups for 652 women with abnormal thermograms, but all the other factors negative, showed the presence of 5 cancers.

4) Our screening done with the 3 exams gives good results. Thermography alone would detect 85.10% of all cancers, the clinical exam 83.33% and high risk 56.14%. A cross examination with the three methods gives us the highest possible precision. In our opinion the main interest of a screening, once it's medical precision is established, is to extend it to the highest number of women. To do this it is necessary to educate with booklets, conferences, etc. all the female population, and to organize some mobile screening units so they may reach even the most distant towns. Computerizing the family history and lectures on clinical findings would give to the whole system a very high flexibility and speed.

P. L. CARNAGHI (Busto Arsizio, Italy)

We have been clinically detecting breast cancer for some years. In case of doubt or suspicion after clinical examination, we carry out mammography, cytological exam of secretion, and biopsy. When our center had the possibility of having at its disposal a thermography unit, we hoped we would carry out clinical and thermographycal screening delaying the other examinations. It has not been possible because of lack of room, time, medical, and paramedical staff. Therefore we used thermography only on patients recommended by doctors for clinical anomalies or women who had risk factors in family history or in clinical instrumental exams. Thus we used thermography on preselected people at « high risk ». Anyway no patient was submitted to biopsy without previously carrying out thermography. At first we noticed that thermography is not so rapid as many persons state. In our opinion five minutes are not enough for a good exam consisting of cooling, taking thermographic pictures from various angle-shots, exact use of isotherm views, evaluation of termal gradients, accurate visit, and recording all data. This is another reason which has persuaded us to use preselected patients. Five groups of thermograms are recognized on the basis of the Amalric classification. In consequence of the above mentioned reasons we saw thermographically only some (3176) of the women that came to be visited, from April 1975 to February 1976. The false negatives prove to be 11%. For evaluating the patients with doubtful or positive thermography, we expressly have considered the TH3 cases together TH4 and TH5 cases because we wished to know the number of patients that needed further thermography checks in a short time, even if they had negative clinical, instrumental, and cytological exams. The false positives were about 16.5%. Therefore if we should organize a screening concerning 1000 women, 15000 exams should be performed in one year, owing to the necessary checks (2-4 times a years) required by doubtful clinical cases (3-6 months), most of which are due to false positive thermographic cases. Considering this experience in thermogram interpretation, we believe that the realization of a thermographic survey in a fairly difficult task. Another consideration from this survey deals with the most frequent thermographic aspects in comparison with stage TNM. We noticed that in T3 a, T3 b, T4 a, T4 b, T4 c either a wide iperthermic area or a dilated asymetrical vessel are more frequent; while in Tl s, Tl, T2 a hot-spot or simple vessel increase in a breast are the most frequent characteristics. In conclusion: 1) Examining our data it seems that the use of thermography is hard as a survey method, while good results can be obtained utilizing thermography only on people exposed to risk. 2) We must pay attention to the above mentioned thermographic aspects relating to the fact that the women coming to our center are in initial stages.

L. Rocchi (Cesena, Italy)

We may synthesize the advantages and disadvantages of thermography in a screening for early breast cancer detection as follows:

Advantages: 1) low running costs, 2) rapidity, 3) repeatability, 4) good diagnostic results, 5) well accepted by women.

Disadvantages: 1) high cost of instrument, 2) need of an experienced operator, 3) low room temperature, 4) tiring of operator.

The average time needed for a thermographic observation is 6/7 minutes. We classified thermographic findings in 5 classes according to Spitalier and Amalric. We found a false negative rate of 9.65%. The false positives were mainly fibrocystic masthopathies. The histologically accertained cancers have been 195, in the proportion of 1 every 300 thermographies done.

M. Pietrojusti (Milan, Italy)

We always associate thermography with the clinical exam in each visit of the patient. Mammography is considered as a more through diagnostic investigation and is used in the cases we notice or suspect of breast tumour. We invite to our center, by letter, all the female population of more than 35 years of age. We consider more carefully women bound to risk and we examine them more frequently. The percentage corrisponding to this group is about 30%.

Results

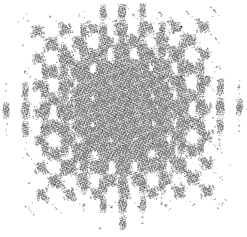
Positive to our exam	62
Cases of unknown istological exam:	6
False positives (i.e. cases that did not evidence *till* now any malignancy)	3
Cases with histologically ascertained tumours:	53

At the first visit, among the 53 ascertained cancers we found 25 (47%) of them, the others presented at the first visit these results:

normal	9
libroadenoma	2
cystic diseases	4
mastopathy	6
nipple secretion	1
suspect	6

Almost all these cases evidenced malignancy after a period longer than six months.

Only among the suspect cases has this period been shorter.



12

Invited papers

E. F. J. **RING** (Royal National Hospital for Rheumatic Diseases, Bath, England)

Computerised thermography for osteo-articular diseases

The assessment of a disease process is dependant on suitable indicators. In diagnosis, treatment or research quantitative assessment methods are needed, for only by this means can the procedure be adequately standardized. Arthritis is often measured by subjective methods, many of which carry large observe-reproducibility errors. Calor and rubor are common indicators of joint inflammation, and these are clearly shown by modern thermographic techniques.

Earlier studies of joint temperature have been limited, since intra articular thermocouples are invasive and unsuitable for routine use. Surface measurements with thermocouples and thermistors are slow and themselves introduce errors through contact and pressure. The two dimensional infra red scan, or thermogram is a rapid and efficient record of temperature, and suitable for temperature monitoring of articular joints.

Studies carried out in this department in Bath over the last 12 years have shown that surface temperature of peripheral joints does relate to the degree of inflammation. For example, examination of synovial fluid aspirated from inflamed joints, shows that changes in biochemistry and cytology occur in direct proportion to the surface temperature of the joint.

Technique

The essential requirement for all quantitative thermographic measurements is rigid standardization of technique [3]. The examination procedure is carried out in a room at 20°C with an infra red thermograph mounted on a special stand. Scanning of all joints is made with the camera on a horizontal mount, with vertical adjustment from 20 cms to 150 cms. Patients are cooled prior to their examination in a curtained part of the room for 15 minutes, with the limbs exposed.

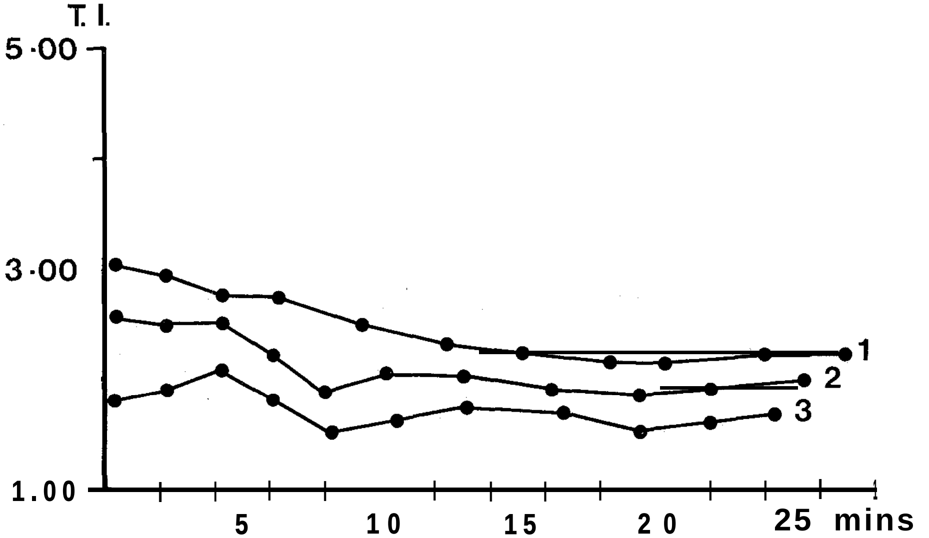


Fig. 1. The fall in the thermographic index of the knees of three subjects cooling in ambient temperature of 20°C.

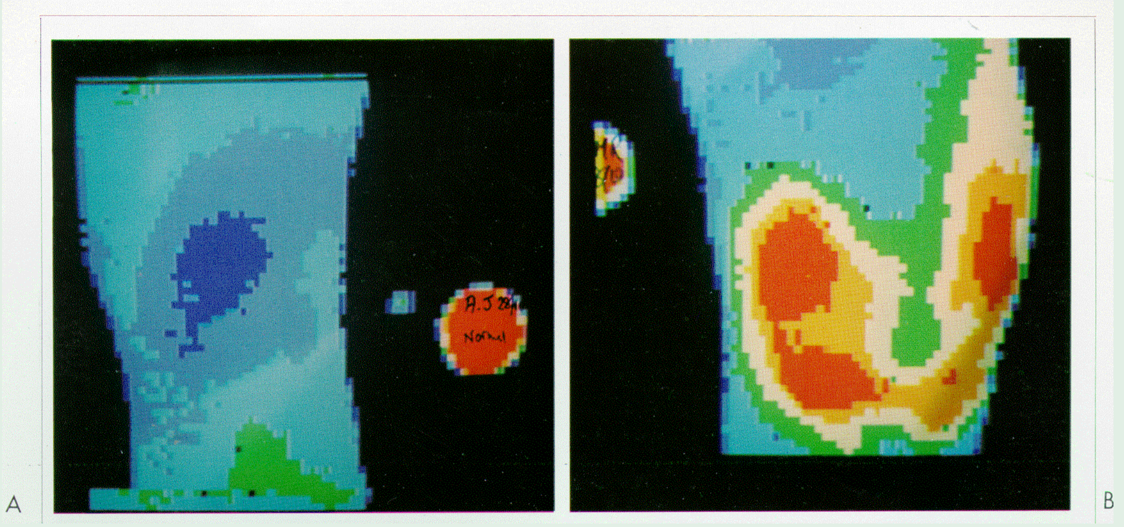


Fig. 2. (A) Thermogram from the computer display of the anterior view of a normal knee showing a cold patella. The reference source (red) is at 32.5°C and the blue isotherms 26-27°C. (B) Thermogram as A from a rheumatoid arthritic knee, with early acute synovitis.

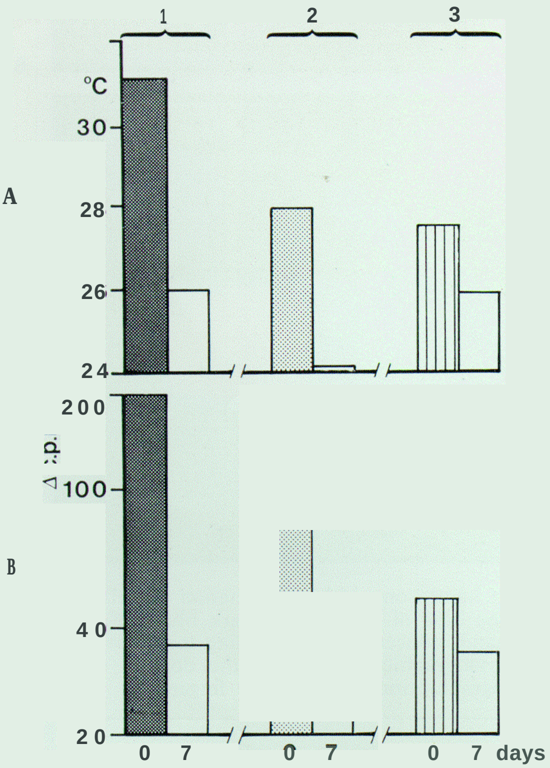


Fig. 3. Comparison of surface temperatures (A) of three rheumatoid arthritic knees (3 patients) with changes in Iodine 131 clearance (B), before and seven days after prednisolone injection.

Standard positions are adopted for each joint and a constant temperature reference usually at 32.5°C included in the picture. Experience has shown that a temperature range of 26-33°C is the most suitable for peripheral joints after cooling at 20°C. However, a second range 28-35°C is used for hands and tibia1 thermograms. The pictures are transferred from the infra red thermograph to a Pd P8 minicomputer, which is compled to a colour television monitor. The thermogram is displayed in a range of colours set at 0.5°C intervals. Each colour always indicates the same temperature and abnormalities are immediately visible. Since the colour image is displayed from digital data, a region of interest may be selected on a 64 x 64 bit x-y axis. The numerical data can be printed at the teleprinter terminal to 0.1°C.

The thermographic index

The method used to quantitate the thermogram was published by Collins [1]. It is based on the proportion of isotherms within a chosen region over a selected temperature range, usually 26-33°C.

The formula $T\ I = \frac{t \times a}{A}$ expresses this calculation

t = baseline temperature 26 or 28

t = difference in degrees between the isotherm measured and that baseline, i.e. at 27.5 (t=26) t=1.5

a = arca in sq cms of each isotherm

A = total area quantitated in sq cms

In practice the area of each isotherm within the selected area is measured and multiplied by its baseline difference. Using half degree intervals, each total is added together and divided by the total area to be quantitated.

Using this formula a scale from 1.00-6.00 is obtained. Normal values are low 2.00 and inflammatory joints are raised up to 6.00. Normal values for this index arc shown in Table I. The rate of cooling of three normal knees using the index is shown in Fig. I. Studies of temperature stabilization, diurnal variation and anti inflammatory drug therapy have been made using this system of quantitation. A total of 8,000 measurements to date have proved the reliability of this thermographic index for peripheral joints.

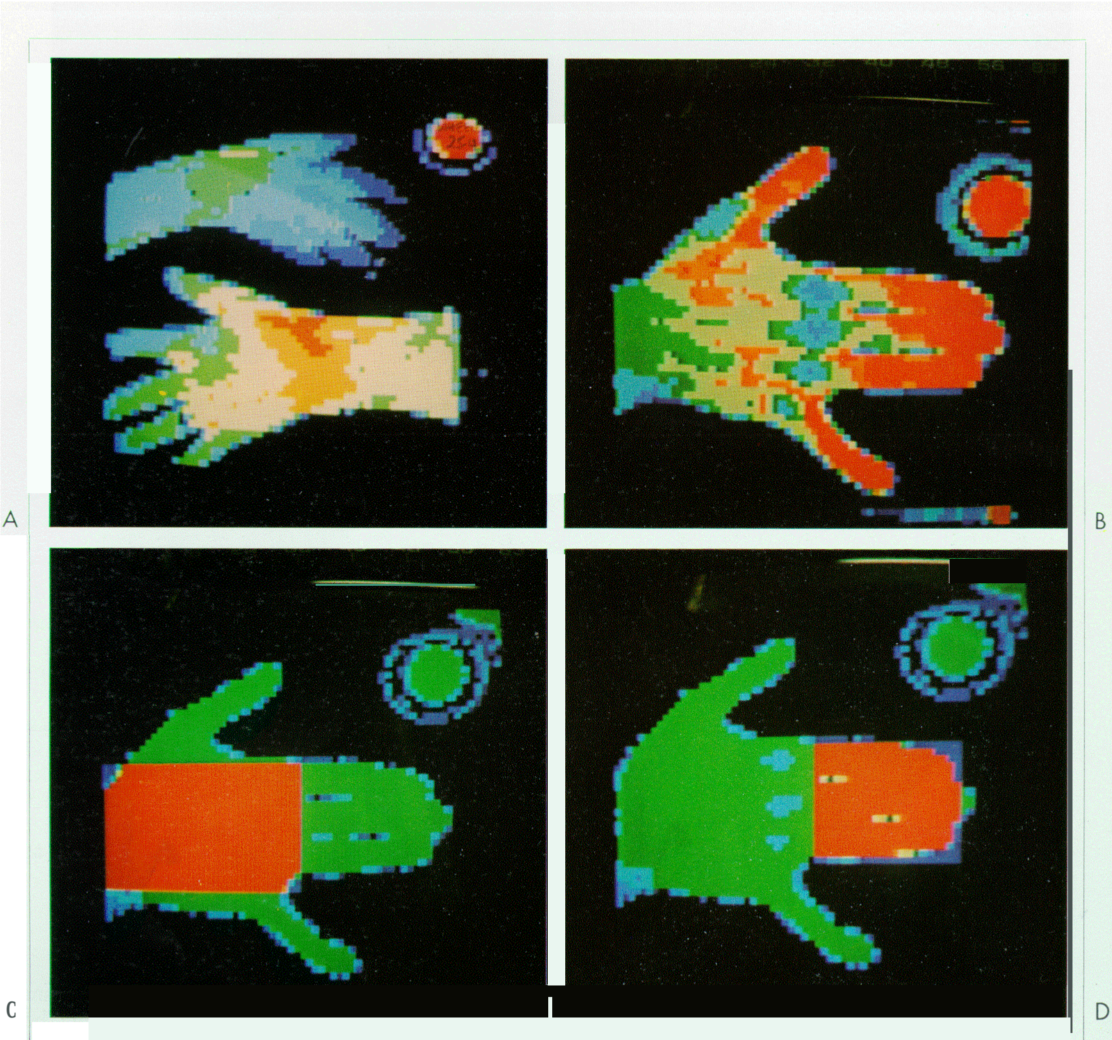


Fig. 4. (A) Thermogram of dorsal surfaces ot a pair of hands, one with inflammation **affecting** the m.c.p. joints and first carpo-metacarpal joint at the base of the thumb. Dark blue-28.0, red = 34.5°C (B) Hyperaemia of dorsum of a normal hand induced by mild cooling for 60 secs in water at 20°C. (C) Area quantitated for the thermographic index from the dorsum of the hand. (D) Area quantitated for the thermographic index from three fingers.

The knee joint

This is the largest and simplest articular joint for thermographic examination. Our patients are routinely scanned in a standing position for anterior views. Single joints scanned this way can be quantitated from a region of interest containing 900 counts, an area approximately 10 cms x 10 cms located over the patella. A normal knee is usually close to 26°C with a characteristic cold patella. Using a reference at 32.5°C (red) the normal joint is seen in shades of blue. In contrast an inflamed arthritic joint marked by synovitis, shows temperature increases, from green-yellow-orange to red (Fig. 2). A chronic rheumatoid arthritic knee may be extremely hot, and show the outline of the joint capsule. Early acute arthritis, however, may show a more localized hyperthermia often in the infra patella area. Lateral views of the knee are also useful and necessary if the patient has a severe flexion deformity or unable to stand. These are conveniently made the patient in a normal sitting position in a chair with the knees flexed at 90". The thermographic index is a little higher in lateral thermograms of the normal knee, and medial views raised even more in some subjects due to the long saphenous vein. These differences, however, are small compared with the increase found in inflammatory joint scans. The injection of infra articular steroids into the knee is an established form of local therapy'. The synovial blood flow is reduced after infra articular steroid injection. This can be demonstrated both by the rate of isotope clearance e.g. Iodine 131 Tc 99 and change in surface temperature (Fig. 3). Thermographic studies of the effects of differing analogues of Prednisolone has shown that even the most insoluble compounds have some systemic effect. By studying the temperature changes in an injected knee and the contralateral untreated joint the local and systemic effects of treatment are shown. The clinical signs of relief from pain and stiffness may last for longer periods, but thermography shows that the inflammation often returns within two weeks of the injection. Increasing the dose of steroid, may improve the initial sharp decrease in thermographic index, but is unlikely to have much influence on the duration of anti inflammatory effect.

Tab. I.

No	Location	*Thermographic index* Mean t. index	Range ± S.D.
10	Lateral elbow	1.93	1.48-2.37
70	Dorsal hands (wrist-m.c.p. joints)	1.73	1.38-2.08
60	Anterior knee	1.65	1.18-1.13
20	Medial malleolus	1.43	0.99-l .87
20	Lateral malleolus	1.34	0.85-l .83
10	1st. m.t.p. (medial)	1.03	0.84-l .23

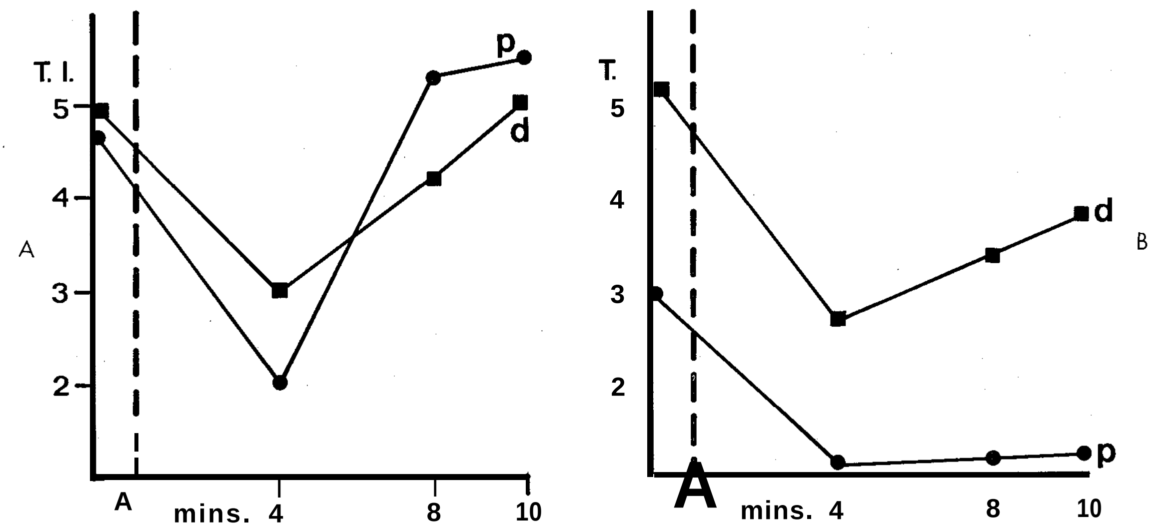


Fig. 5. The change in thermographic indices from the two areas shown in Fig. 4c (■—■) and 4d (O-O) of a normal (A) and rheumatoid Raynaud (B) hand.

The hand

Thermograms of the dorsal surface of the hand are made against a small board held by the patient against the thorax. This serves as a heat screen excluded unwanted radiation from the body, and has a small temperature reference attached. By using a temperature range of 2835°C values for the thermographic index fall within the range of other peripheral joints. The areas selected for quantitation are 1) a rectangle from the wrist to metacarpal joints; 2) a rectangle from the metacarpal to p.i.p. joints of the middle three fingers (Fig. 4).

For the assessment of anti inflammatory drugs the wrist-metacarpal area is measured from both hands, together with both knees. These four sites form a useful composite from which the effect of therapy can be judged. Other specifically inflamed joints can be added to this group as appropriate. In Raynauds disease, the fingers are cold, and fail to produce reactive hyperaemia on

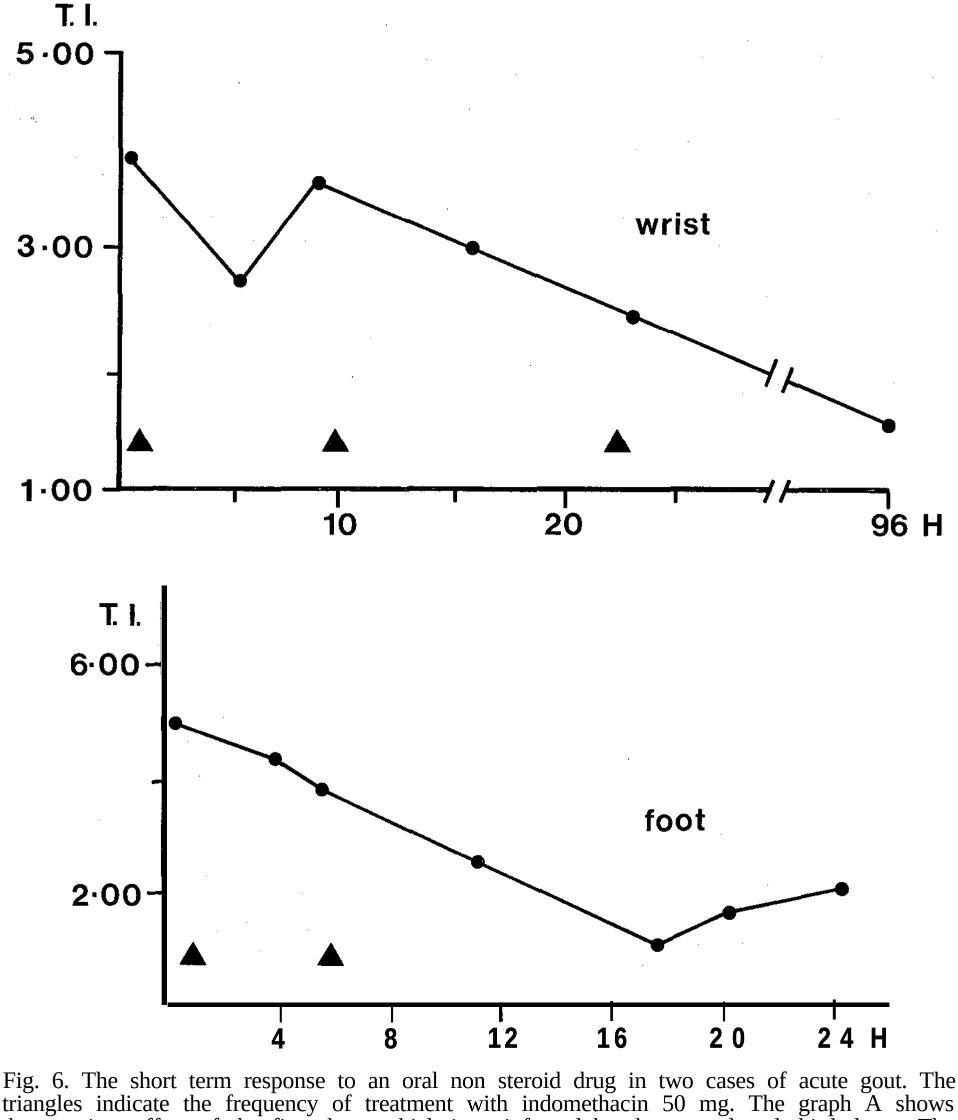


Fig. 6. The short term response to an oral non steroid drug in two cases of acute gout. The triangles indicate the frequency of treatment with indomethacin 50 mg. The graph A shows the transient effect of the first dose, which is re-inforced by the second and third doses. The graph B shows the duration of two 50 mg doses, maximal at 18 hours.

mild cooling. The two areas of hand thermograms are quantitated, and the hand is cooled for 1 minute in a waterbath at 20°C, using a plastic glove to avoid wetting. The normal hand produces a hyperaemia in the fingers within 4 minutes from cooling. The thermographic index from the fingers therefore, becomes greater than the dorsum of the hand. In Raynaud's disease the reverse is seen, i.e. hyperaemia up to the metacarpel joints, and a cold low index in the fingers (Fig. *5).* We have used *Inisitol* Nicotinate (Hexopal, Sterling Winthrop) a peripheral vasodilator, on patients with Raynaud's disease. Improved peripheral blood flow has been shown in these patients using the hyperaemia test. The thermographic index is a convenient means of quantitating this reaction.

The elbow joint

Lateral thermograms of this joint in 90° flexion are conveniently made, the heat shield and reference source held against the body, the patient sitting sideways on to the camera. A square region of interest is located over the joint-and the index calculated from the temperature range 26-33°C.

The foot

The planter surface of the foot is difficult to position for thermography, however lateral and medial views present no problem. The malleolus forms a convenient focus for quantitating the ankle, and a square region is measured from this centre. In cases of gout, the 1st metatarsal joint is often inflamed. Thermograms of the medial foot can be quantitated by measuring a narrow rectangle from the toe to the heel. Response to Indomethacin has been clearly shown by this method' (Fig. 6).

The effect of drug therapy

Using the standardized technique described, we have been able to use the thermographic index

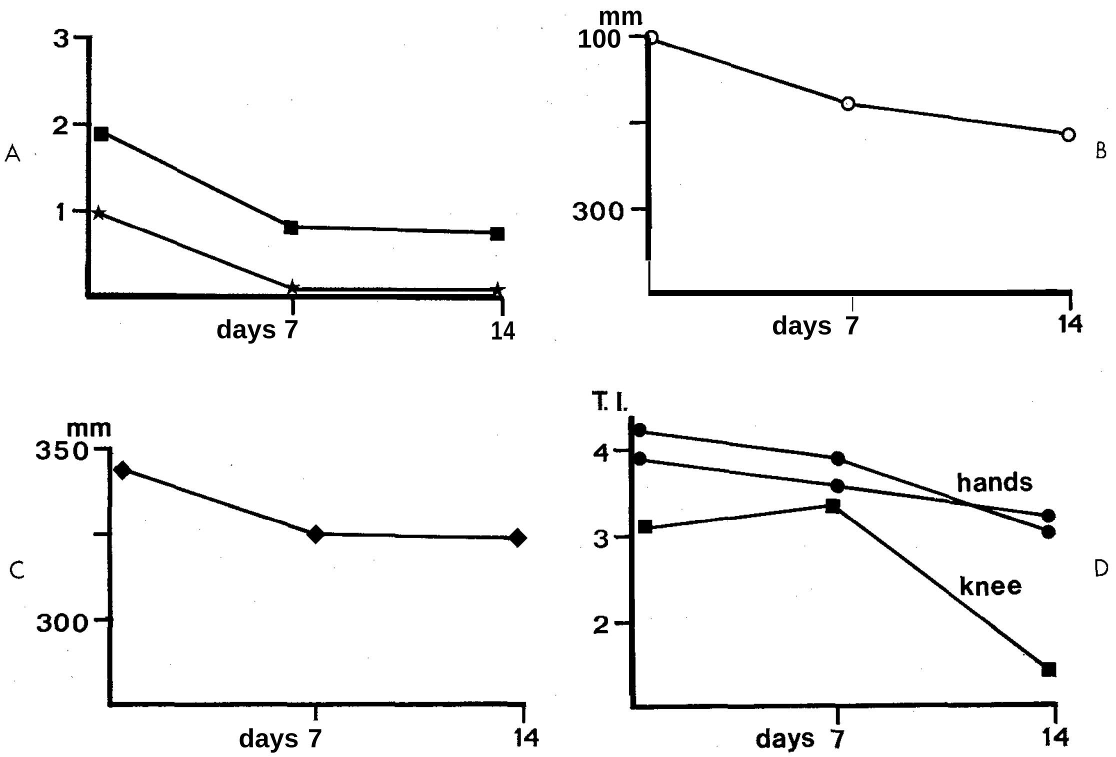


Fig. 7. Four graphs showing the anti-inflammatory effect of a non steroid compound (Benorylate) shown by the thermographic index (A), sphygmomanometer grip test (B), subjective pain scores (C), and finger ring size (D). The thermographic index shows a reduction after 2 weeks therapy in an inflamed knee, not reflected in the pain score, which was improved at 1 week. The slow fall in the hand indices however are comparable.

as an objective measure of anti intlammatory therapy. Analgesic Drugs have consistently failed to lower a raised index, but any treatment which is reducing inflammation, can be shown to lower the index. In a cross over study with Parecetamol and Aspirin, it ha5 been shown that the latter is effective in lowering the index. Other non steroid drugs have been studied, and exhibit greater or lesser reductions in inflammation. In comparison with other clinical measurements, grip strength, morning stiffncss. pain. E.S.R. etc. the index ha5 contributed very useful data (Fig. 7). New anti inflammatory compounds have been studied, and can rapidly be assessed for potency at the prescribed dosage. Other drugs which are not thcmselves considered anti inflammatory i.e. cytotoxic agents, are in USC in some rheumatology clinics. Careful management of the patient is essential, with such treatment. Thermography has provided us with a valuable tool for monitoring such treatment *.

The success of any system used for clinical measurement is dependant on several factors. It must be sensitive to specific changes in pathology, and relate to the disease process. It must also be capable of simple standardization and be acceptablc to clinician and patient. Infra red thermography suitably quantitated does meet these requirements. It is a reliable and objective means of noninvasive studies in the diagnosis and management of osteo-artilular diseases.

REFERENCES

1. **COLLINS** A. J., **RING E. F. J., CoSH J. A., BACONon** I'. A.: Quantitation of thermography in arthritis using multi isothermal analysis. I. The Thermographic Index. Ann Rheum. *Dis., 33,* 113-I 15, 1974.
2. **HOLLANDER J. L., BROWN E. M., JessAR. R. A., Brown** C. Y.: Hydrocortisone and cortisone injected into arthritic joints. J.A.M.A., 147, *1629-1635,* 1951.
3. **RING.** E. F. J.: The Thcrmographic Assessment of Anti Inflammatory Drug Therapy in Arthritis. M. Sc,. *Thesis,* University of Bath, 1975.
4. **Ring** E. F. J.: Thermography and Rheumatic Diseases. *Bibliotheca Radiologica, 6,* 97-106, 1975, Kargcr (Basel).
5. **KING E. F. J., COLLINS A. J., BACON P.** A., Cosh J. A.: Quantitation of thermography in arthritis using multi isothermal analysis. II. Effect of nonsterateroidal anti inflammatory therapy on the thcrmographic index. *Ann. Rheum. Dis., 33,* 173-177, 1974.

C. J Huber (Thermography Department, Radiology Service,
Country Hospital, Creteil, France)

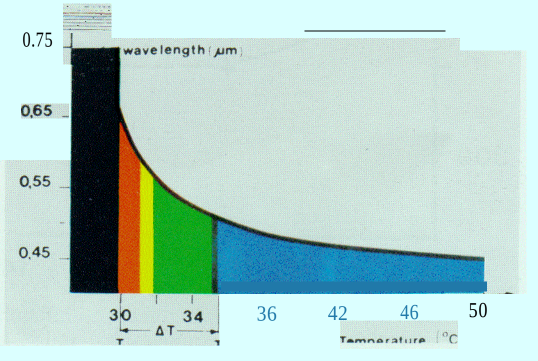
Cholesteric thermography: comparison with infra-red thermography in clinical use

INTRODUCTION

Thcrmology is a science that uses different methods to study temperature differencea. One of these methods is cholesteric thermography. It has been used for quite a long ago, but it was so difficult to perform, that it had fallen into disuse. Actually with some new apparatus. this kind of thermography can find some interesting uses. This kind of thermography gives us information that we will compare with infra-red thermography.

MATERIAL AND METHODS

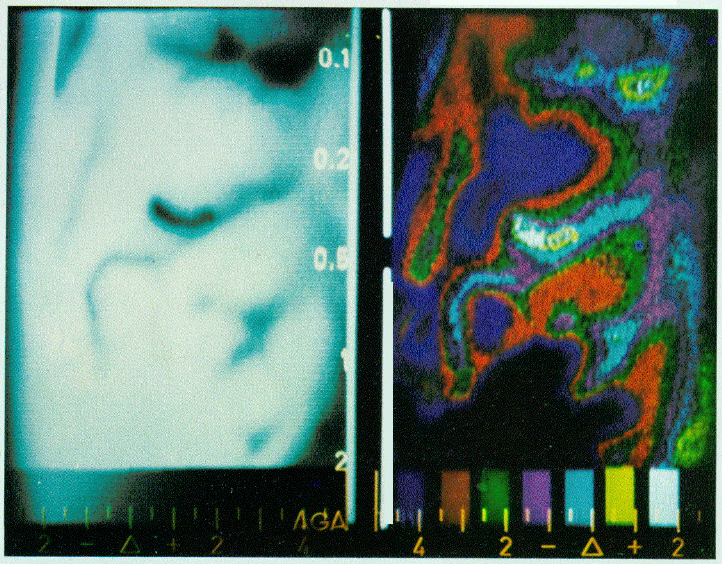
Cholesteric thermography is done with liquid crystals. Liquid crystals are an intermediary state of matter, between solid cristal and liquid. In this state called mesophase, the molecules of some crystal can slip against each other, a spatial structure remaining between them. It is different from solid crystal structure where there is a definite spatial arrangement, and it is also different from the liquid state where there is no arrangement between the different molecules which are completely independant. There are three different typcs of liquid crystals: nematic; smectic; cholesteric. These three differ in the nature and in the degree of the ordcly arrangement of their molecules. We will compare them with simple geometric ana-



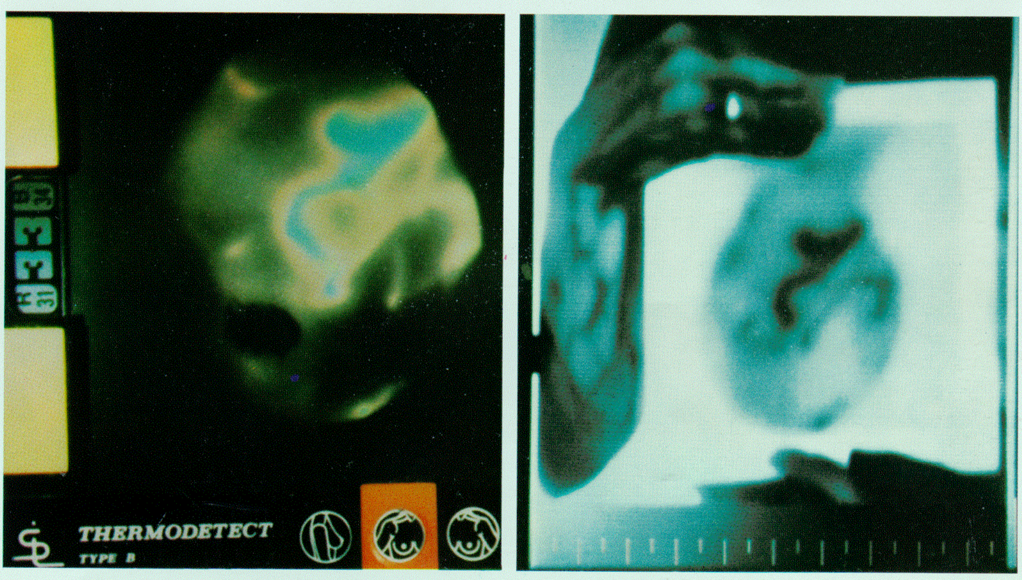
Graph. 1. Relationship between colour and temperature.

logie: nematic has the lowest degree of order of the molecular arrangemcnt: all the molecules arc parallel and have one axis pointing in the same way. Smectic: the molecules in this casc are not only parallel but their position along one axis is fixed So they arc organized side by side in group5 or layers. *Cholesteric: the* arrangement consists of layers, within which each molecule *lies* flat and is parallel to each other; successive *layers* being rotated a fixcd amount from the previous layer. It is this last kind of crystals that we use in thermography. They are formed by esters of cholesterol such *as* Acetate, Bcnzoate, Stearate etc. They have a special optical property, studicd by Ferguson around 1966, of polarizing light and scattering light of certain colors at particular temperaturcs. Since the iridescent color5 exhibited by the liquid crystal materials arc caused by a small part of incident light being scattered back to the eye, the colors are most readily seen if the liquid crystals are observed against a dark or black background. It is possiblc to predctcrmine tem-

Fig. 1. A) Vascular pattern near view with AGA camera: grcy scale mode; color5 mode. B) Vascular pattern with cholcsteric sheet. C) Vascular pattern with ACA camera through cholesteric sheet in grcy scale mode.



A



B

C

perature range with the different mixtures of cholesteric esters. Some can extend the temperature scale and Some can move the temperature range on the general temperature scale.

We have a graph between wave length and temperature as shown in Graph 1 for a predctermined mixture: warm is represented in blue and cold in red or black; between we have yellow and green. It It is possible to have different mixtures to cover all the temperature range we want. Those mixtures were first applied to the skin after painting it in black. It was a long, difficult procedure and bothersome to the patient. The skin had to be completely rewashed if a good mixture was not used at first. The procedure was also expensive, crystals being thrown away after use. This was avoided by applying crystals not on the skin but on some predarkened sheets that

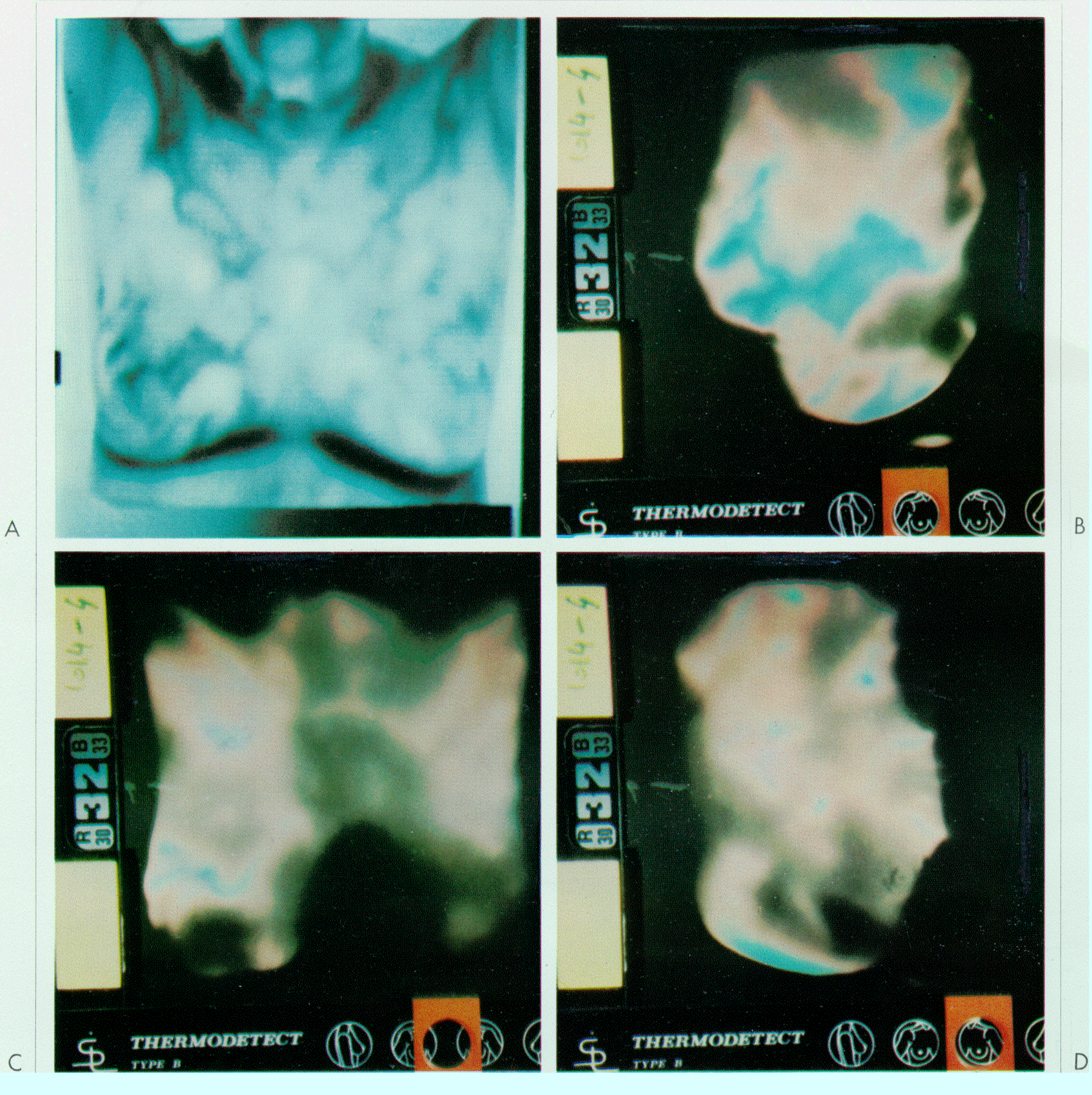


Fig. 2 Right brcast cancer: hypcrthermia of the right breast with hypcrvascularity, (A) AGA camera in grey scale mode: (B, C. D) cholesteric thermography of the same patient. (B): right breast; (C): middle wiew; (D): left breast.

are applied on the skin. The mixture was also fragile and instable, being destroyed in a short time. So the crystals were put in micro-capsules to avoid their coming in contact with air. Thus we had some sheets of different temperature ranges that we can apply against to the skin to measure temperatures by differences of color. We needed to have some references and to protograph these sheets. They were then put in a square frame, and the problem of reflected flash-light was solved by polarized lenses. The square frame was to let the sheet lie gat. By this means we have actually created some special apparatus that can be used easily everywhere.

Sheets can be used by direct examination applied against the skin. And we can photograph the thermal pattern with a camera.

COMPARISON WITH INFRA-RED THERMOGRAPHY

We know that in the body heat comes from metabolism in muscles, brain and liver. The heart is only a pump, the vessels carrying heat everywhere. Cancer is an inserted reheater in the circulation. The skin is only a radiator and one measures heat, coming from underneath by radiation, with an infra-red camera, or coming by conduction, with thermocouples and cholesteric sheets. The infra-red camera shows variations of temperature normaly in black and white, one or the other being warm or cold. The color picture is only an artificial way of calculating easily the differences of temperature by the mean of the isotherms, the color scale being arbitrarily established. For cholesteric thermography the picture is always colored. It is also a kind of isotherm but without a fixed width and with an obligatory succession of colors: from cold to warm black, red, yellow, green, light blue and dark blue (Fig. 1). The exemple shows the difference between these two kinds of thermography in examining the same patient with both methods (Fig. 2).

LIMITS OF METHODS

Cholesteric thermography shows only a little area; it is like a puzzle where one needs to put one piece against the other, keeping the different parts one had examined in mind. Since some pressure must be applied to the sheets for exams of larger areas, the heat distribution is disturbed somewhat. It is more difficult to record exact differences of temperature in degrees between two parts of the body by means of colored references. It can only be used for breast thermography. But it is easy to carry, not really expensive, and it can be used by every clinician to obtain a quick determination of thermal pattern. Infra-red cameras give better views of all the body but need more room; and they are more expensive. They can not be moved easily, but they gives exact differences of temperature. They have a big disadvantage which is the exact reality of measurements, because they don't measure directly temperature but a lot of radiations. This depends on an emissivity coefficient and on the intervening atmosphere; it depends also on the detector used. They are also fragile and need more precautions during use.

But the difficulties of both methods show that they can be used for different purposes.

Closing lecture

M. E. J. HACKETT (The London Hospital, Whitechapel, London, England)

The place of thermography in medicine

Thermography is an excellent method of examination useful in many fields of which the majority of our medical colleagues are ignorant. Its place at the moment is in the novelty section of medical investigation and general medical opinion in that it is a jet aged entity not to be taken seriously. Partly because of this it is being used by a few enthusiasts and is in danger of remaining in this situation and not coming into general use.

It has been said about thermography that it will not succeed unless it can give an answer to a problem that no other method can. Though this is not correct there is an element of truth, in that the best method of, as it were, selling thermography to our colleagues and thus ensuring its general acceptance is by highlighting the things that it can do which cannot be done by other methods. If we do not do this then thermography will fail in that it will remain an investigation used by a few enthusiasts. It is also important at the same time to point out the advantages of thermography as a form of investigation. When this education has taken place the other uses of thermography will be accepted. The advantages are worth reiterating and they are:

1) **Complete safety.** The investigation is passive. There is no necessity to touch the area being examined, in fact it is contra-indicated. Since there is no interference with the patient no harm can be done.

2) Lack **of pain.** There are not many investigations where some discomfort is not experienced. This must be taken as an advantage.

3) Lack of invasiveness. This is of course conducive to more accuracy and is more reassuring for the patient.

4) Safe and easy reproducibility. This is essential in a scientific investigation especially if it is sequential. The fact that this is now possible and also with the introduction of standardisation, thermography must be taken more seriously scientifically for too many papers have been written on clinical impression. This should no longer occur. Hard scientific proof of the efficacy of thermography has to be presented to make it generally acceptable.

5) Low running costs. In these hard times this must be an advantage. Generally the impression is that thermography is expensive, an impression which must be corrected. Once the initial cost of the equipment is met, only the liquid nitrogen and the film are ongoing expenses. Bearing these factors in mind, if thermography can give as good results as other methods of investigation of a problem, then thermography is the method of choice and our colleagues must realise this.

The argument that is being developed is that since we have a valuable diagnostic tool in our hands we must make sure it comes into common use.

It is worth looking at thermography in the four different contexts in which it is used. They are:

1. As an adjunct to another procedure which increases the accuracy of both.
2. As the investigation of choice where it is superior to any other method. This is the area in which more work should be done to help to establish thermography.
3. As a prognostic guide.
4. As a measure of the efficacy of some form of treatment.

A) THERMOGRAPHY AS AN ADJUNCT

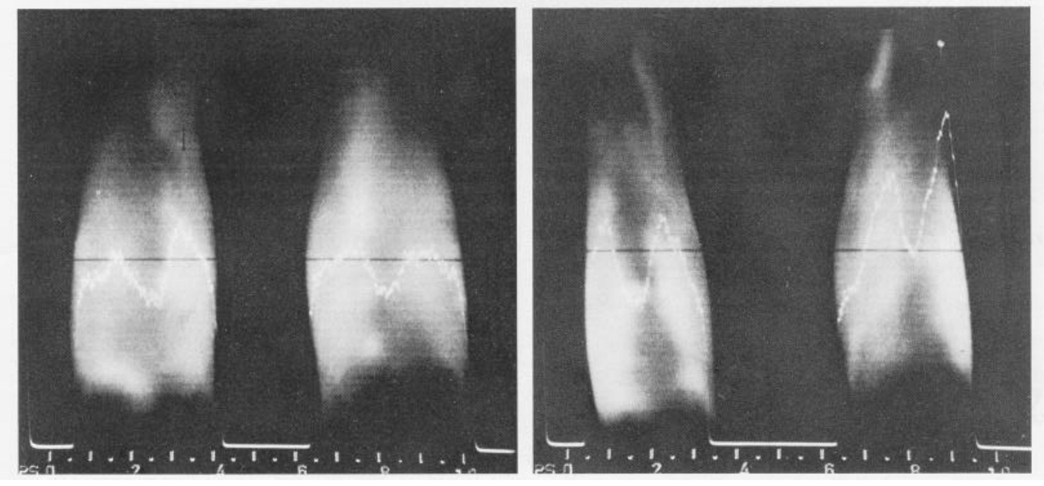
The field which is best known in association with thermography is breast cancer and its importance is in no doubt but it is this field that has caused the acceptance of thermography to be delayed. The reason for this is that as thermography has developed both technically and as a diagnostic tool the premature hope for it as the answer to the early diagnosis of breast cancer has gradually faded so that now we are in the present position of knowing that it is too inaccurate to be used by itself and, in fact, it is only to be used to make the results of mammography better. In spite of this most thermography meetings are still hopelessly overweighted in presenting this aspect of thermography. Many medical men hoped that thermography would be the early warning system which would improve the mortality figures for breast cancer which have remained virtually static for thirty years. When this did not occur they unfairly assumed that thermography was of equally limited use in other fields. This, of course, is not true. In spite of it not being able to give the necessary early diagnosis there are various facts which it supplies which are useful.

We know that a patient with a suspicious thermogram is ten times more likely to develop cancer than the normal. It allows us therefore to find high risk patients and study them in conjunction with mammography which gives the best chance of early diagnosis and therefore better prognosis. Young women on the pill with nodular breasts can be followed adequately with thermography alone by taking a thermographic base line which normally changes very little. However, thermography basically can only be used with mammography. If we wish to further the cause of this science less emphasis must be placed on breast cancer and more on other spheres.

A similar situation with thermography as an adjunct exists in the study of solitary nodules in the thyroid. A nodule, if it is cystic, has little risk of cancer and can therefore be left alone or aspirated, thus avoiding surger. However, if the nodule is solid it should be removed surgically because of the risk of cancer. The use of thermography with ultrasound enables differentiation of these nodules. The results of thermography and ultrasound by themselves are reasonably good but if the diagnosis is the same using both methods the results are almost 100% correct. This use is valuable as the diagnosis previously was by radioactive iodine with not very good results. Using these systems in conjunction unnecessary operations can be avoided.

In the study of secondary bone cancers thermography by itself has an 87% true finding rate and gives a more accurate indication of the extent of the disease than normal X-ray and sometimes gives an earlier diagnosis in the lumbar region. In conjunction with isotope studies better accuracy and earlier diagnosis are brought about. Thus we see that thermography plus another investigation can be of great value but when thermography can suply the answer to a problem by itself it must be more impressive and leads people to appreciate its worth. Therefore it is important that more notice is taken of and more work done on these methods of choice.

A



B

Fig. 1. A) A normal supine thermograph of both calves before exercise with typical thermo-profile across the central calf. The skin overlying the subcutaneous tibia is cooler (darker) than the skin overlying the calf on either side. B) After-exercise pattern shows accentuation of the pre-tibia1 cooling seen in the normal resting pattern.

B) THERMOGRAPHY AS A METHOD OF CHOICE

1) Burns. In the modern treatment of burns, deep and deep partial thickness burns are excised and the area grafted so the diagnosis of the depth

of burns has become increasingly important. This can be very difficult and there are over twenty known methods possible, none of which is simple, so clinical estimation is almost always used. A full thickness burn is 2.5°C colder than comparable skin and a deep dermal is 1.5' colder, so it can be seen which areas of a burn should be excised and which areas left. This reduces the amount of surgery required and early diagnosis enables surgery to be performed before sepsis intervenes as well as preventing unnecessary surgery in partial thickness burnes. Over 300 burned areas have been studied using thermography and compared with the clinical impression of burns experts; thermography was shown to be three times more accurate and must therefore be the method of choice.

2) Deep vein thrombosis. Mortality is increasing in tbrombo-embolic disease, therefore we need early diagnosis and effective prophylaxis. Cooke and Pilcher have shown that raised temperature and delayed cooling on exposure of the thrombosed limb is an early sign of deep venous thrombosis which can be detected thermographically when not apparent clinically. In a series of 53 thromboses detected by phlebography, 51 had been previously suspected thermographically. In the same **series** 56% of the cases were not diagnosed on clinical examination. Similar results were obtained by Henderson et al., when comparing thermography with radioactive fibrinogen. Henderson also points out the great potential of the post exercise test in high risk patients (Fig. 1 A-B; Fig. 2 A-B).

Here is a field where because of the advantages of thermography it would appear to be the investigation of choice. The mortality from D.V.T. is high and if we are to use thermography to save life then there is surely more scope here than in cancer of the breast. It would appear that if the true worth of thermography in medicine is to be appreciated more work should be done in spheres such as this.

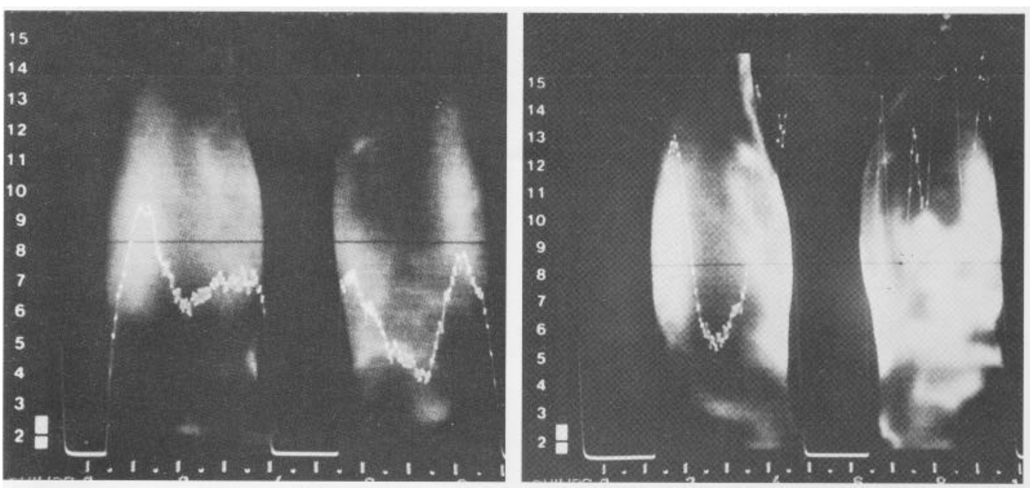
A  B

Fig. 2. A) A normal resting thermograph of both calves. B) An abnormal after-exercise pattern showing -dilated veins over the pre-tibia1 area more marked in the left calf (on the right of the picture) than in the right calf (on the left of the picture). This thermographic image is obtained by a mirror suspended over the patient hence inversion of left and right. This patient sustained a bilateral deep vein thrombosis. There is a more than two-fold increased incidence of deep vein thrombosis in a calf showing an abnormal after-exercise pattern.

3) Testing the viability of flaps either traumatic or planned.

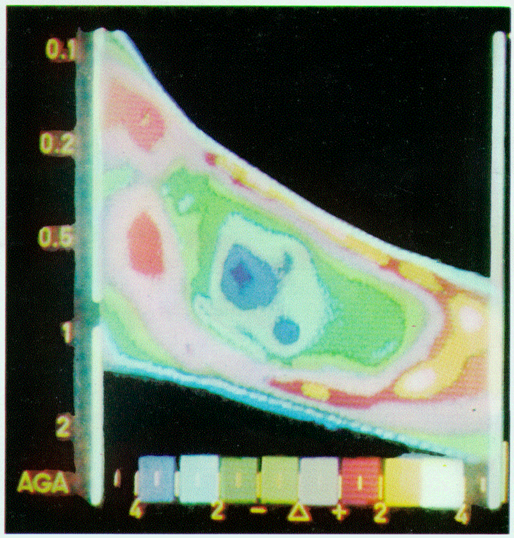
In plastic surgery when a flap is raised it is left for three weeks to permit adequate circulation to be acquired by the flap. It is then divided and usually succeeds. Thermography is a simple way of seeing if the flap is ready to move before three weeks or if it should be delayed at three weeks as it would fail if divided. Weeks of hospital care can be saved using this method which is the one of choice, as there is no other effective and simple method available. Similarly traumatic flaps are often raised in accidents and sewn back in the hope that they are viable. It is a considerable time before they are found not to be and have to be excised and the area grafted. This wasted time can be avoided by thermography (Fig. 3 A-B-C-).

4) Malignant melanoma. Spitalier's work in diagnosing malignant change in melanotic lesion5 using thermography is associated with a prognostic index depending on the increase in temperature and the presence or absence of a flare. Malignant melanoma is still bedevilled by ignorance as to the best form of treatment but any improvement in diagnosis especially without any physical interference must be a useful step forward in this vicious disease. The most reliable method is excision biopsy but if this must be done the necessity to remove large areas of tissue is still in doubt, frozen section is often unreliable and large lesion5 and lesions on the face present special problems. An 80% chance of the correct diagnosis as given by thermography preoperatively makes this method the screening test of choice.

4) Amputation sites. In an arteriosclerotic patient it is important to be sure that if an amputation of the lower limb is intended, if possible a below-knee amputation is performed because of more high incidence of re-operation occurs and this is because no scientific assessment of the site of amputation has been made because there is no mobility, lighter prostheses and the 30% chance of becoming a bilateral amputee. The assessment is usually done clinically but with the use of thermography more certainty of success of the operation can bc obtained. The main factor for success is the viability of the skin flaps and this can be measured. In many amputation series a simple one available. If a busy clinician is dealing with a common entity, which amputation is, he will only use scientific tests if they arc simple and quick. The simplest and quickest for assessment of the amputation site is thermography. If its value can be demonstrated to surgeons performing these operations it will come into common use.

A


B

C

Fig. 3. A) Persiatent ulcer of malleolus to be treated with free flap and microvascular anastomosis. B) Immediatelv post-operatively. C) Thermograph showing marked temperature loss over free flap which was a complete failure.

5) Localisation of perforating varicose veins. Patel's work ha5 shown how little difference there is between phlebography and thermography in this very common field. With the advantage5 of thermography over phlebography, i.e. lack of invasiveness and no irradiation, thermography is the better method. In this sphere a5 in many other5 the commonest diagnostic test is the purely clinical one which will show up gross clinical defects but not the less obvious. If clinicians are to be persuaded to use a scientific method in a common condition it must be reliable, safe, and simple, which thermography is.

6) Carcinoma of the larynx. Recent work has suggested that the time required to wait for surgery following irradiation of the larynx can be estimated using thermography. Since no other method is available this must again be the method of choice.

7) **Microvascular surgery.** This is a speciality which growing very quickly and has many possibilities. At the moment it is used manly in the reimplantation of severed digits and hands and in the free transfer of pieces of tissue instead of using flaps. The success of surgery has to be monitored very carefully because if thrombosis occurs the anastomosis must be treated surgically without delay otherwise the tissue supplied dies. Baudet of Bordeaux who is one of the leading experts of this kind of surgery maintains that thermography is the best monitoring system to warn of the necessity for further surgery and also as a prognostic guide. He maintains that if replantation of a digit is fully successful (arterial and venous drainage perfectly re-established) and the temperature recorded on the second or the third post-operative day is either normal or more often 2°C lower than the contralateral healthy finger. By the first week the temperature reaches normal values. Sometimes a hyperthermia is observed.

If replantation shows complications thermography provides useful data in the first post-operative day. In the event of arterial thrombosis with complete devascularisation the temperature drops quickly after the occurrence of the complication and this temperature drop reached 8 to 10°C compared with the contralateral healthy finger. In the event of venous embarrassment the temperature drop may be 4°C or slightly more. If the temperature drop reaches the value of 6°C this proves that no tissue survival can be expected.

If the replantation is complicated by arterial or venous problems but is not followed by complete failure of the replantation (this failure usually occurs in the first four days) a thermogram at the end of the-first week gives interesting data on the extent of tissue survival that can be expected. Thermography is also interesting in crushing injuries of the hand and in several instances a thermogram done earlv after the iniurv has shown that no finger survival was to be expected while the clinical examination was questionable.

Thus we see thermography being used in a brand new exciting field as a method of choice and probably this is virtually unknown.

C) THERMOGRAPHY AS A PROGNOSTIC GUIDE

Microvascular surgery has been mentioned and it is also useful in ordinary arterial surgery as it is one of the best indications of perfusion of tissues. In malignant melanoma, Spitalier has shown the significance of a thermographic flare and its use as an indicator of a liability to breast cancer is well known.

D) THERMOGRAPHY AS A MEASURE OF EFFICACY OF TREATMENT

Of more significance is its use as an index of the efficacy of treatment in several conditions. Rheumatoid arthritis is a good example of this and Ring's work in this field on the use of the therapeutic index based on a multi isothermal analysis of a joint area permits thermography to tell not only if a method of treatment is effective but how effective. This quantitative aspect is an invaluable advance and must improve the chances of thermography being taken seriously if more people know of it and more work is done which it.

n

The possibilities for the use of thermography in medicine are numerous - a few have been mentioned but many have not. It is still a comparatively unexplored field in which the potential will not be fully realised unless it comes into more common use. The heartening events which are likely to help here are the standardisation of the use of thermographic equipment and the formation of more thermographic societies. The former would mean that all investigations anywhere are comparable and thus higher scientific standards could be achieved. The latter would help to stimulate advances in thermography and also, more importantly at the moment, educate the medical masess in the use of thermography.

Free papers: *technical advances*

F. Montevecchi, B. Abbiati, C. Parrella, F. Pizzutilo (Milan, Italy)

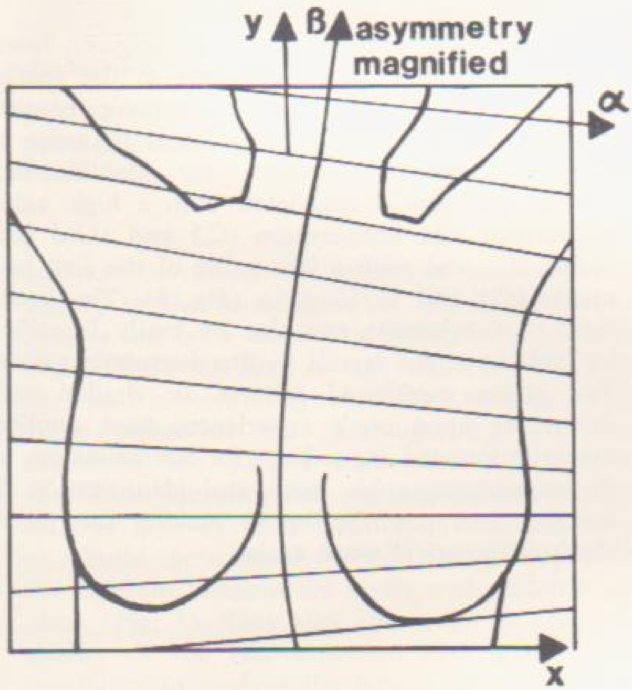
Automation and diagnosis in thermomammography

INTRODUCTION

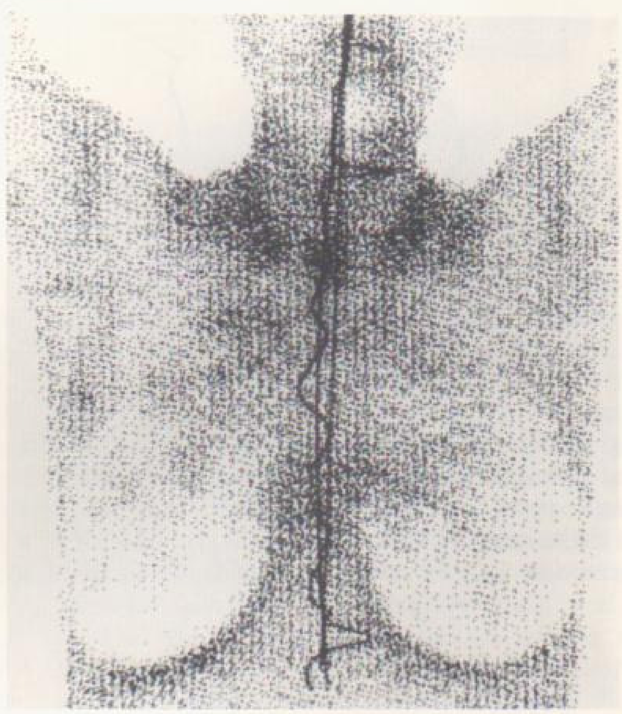
In recent years several factors stimulated a growing interest in the application of computers to the analysis and treatment of thermographic data. Emphasis on mass screening, under due limitations inherent in investigated pathology, requires carefull examination of automation's capabilities to speed up investigation time and to lower the price/efficiency ratio of the diagnostic procedure. The Bioengineering Group of the CNR (National Research Council) CNPM of Milan and of the Institute of Applied Thermodynamics of the Politechnic of Milan in cooperation with the Sanitary Physics Department of the Institute for Investigation and Healing of Tumors in Milan started in 1975 a joint research effort aiming at developing and exploiting automation capabilities in thermomammographic diagnosis. The following steps in research work have been considered and carried out: *a*) collection, digitalization and monitoring of thermographic data; *b*) normalization of thermographic maps; *c*) isothermal line representation; *d*) Fourier analysis of data; *e*) automatic identification of breast positioning. Present efforts are dealing with the following topics: *a*) evidencing of superficial vascularization; *b*) classification of vascular individual patterns; *c*) development of dedicated microcomputer systems for data collection and retrieval; *d*) statistical investigations and follow up of healthy and pathological subjects.

PRESENTATION OF RESULTS

In order to make possible the comparison of maps of different subjects and chiefly to follow the clinical history of a subject, geometrical mispositioning has to be removed from the data. To



A



B

Fig. 1.

13

accomplish normalization we have assumed a general situation (Fig. 1) in which α and β co-ordinates are determined by optimizing a symmetry descriptor defined as:

$$\Phi = -\{f[t=t(\alpha, \beta)] - f[t=t(-\alpha, \beta)]\}^2$$

Choice of f(t) function is dependent upon stress on computer time or on other considerations; Fig. 2 shows some of the assignable f(t) functions. Rotation analysis can be approached by means of harmonic analysis and phase angle inspection:

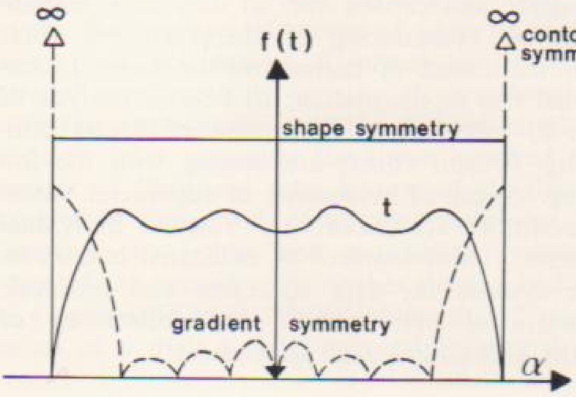


Fig. 2.

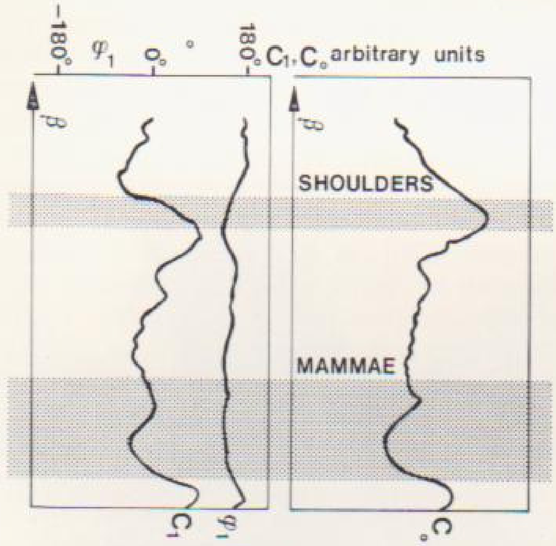


Fig. 3.

Fig. 3 shows the mean value (C_0) line and the first harmonic (C_1) amplitude and phase angle (ϕ_1). Based upon (ϕ_1, ϕ_3, ..., ϕ_{1+2n}) (n integer) data an estimation of body rotation is possible, and a correction may be introduced with the help of a spatial model of thorax and breast (Fig. 4). Interesting results have been obtained in the spatial identification of breasts. The harmonic content of line signal has proved significant in order to support quantitative criteria for identification.

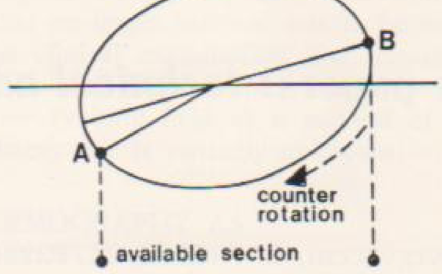


Fig. 4.

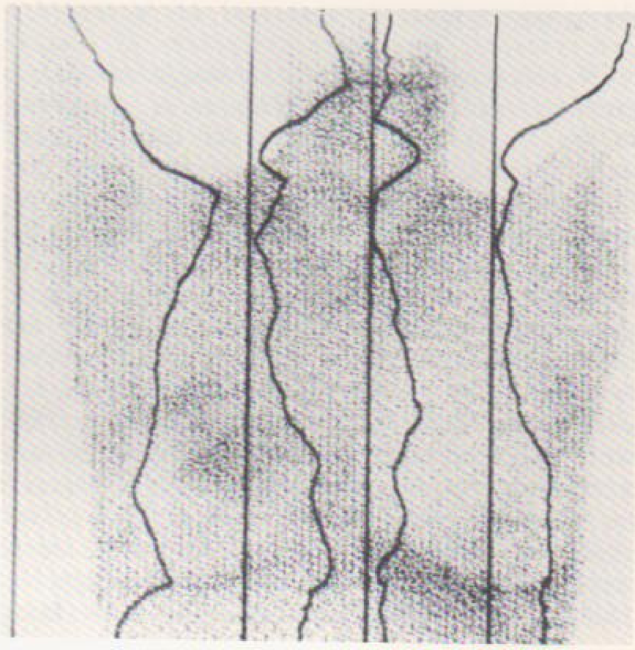


Fig. 5.

Neck position is associated with a high value of average line temperature (C_0) and third harmonic (C_3) and with a low value of the first harmonic (C_1) and C_1/C_0 ratio (Fig. 5). The lower limit of the breasts can also be easily identified by looking at the trends in line harmonic values. The above mentioned criteria, or similar ones depending upon one's experience, seem applicable in automated procedures for normalization of thermomammographic maps and identification of breasts; thus contributing to making the physician's diagnostical work easier.

Free papers: *technical advances*

F. Montevecchi, B. Abbiati, C. Parrella, F. Pizzutilo (Milan, Italy)

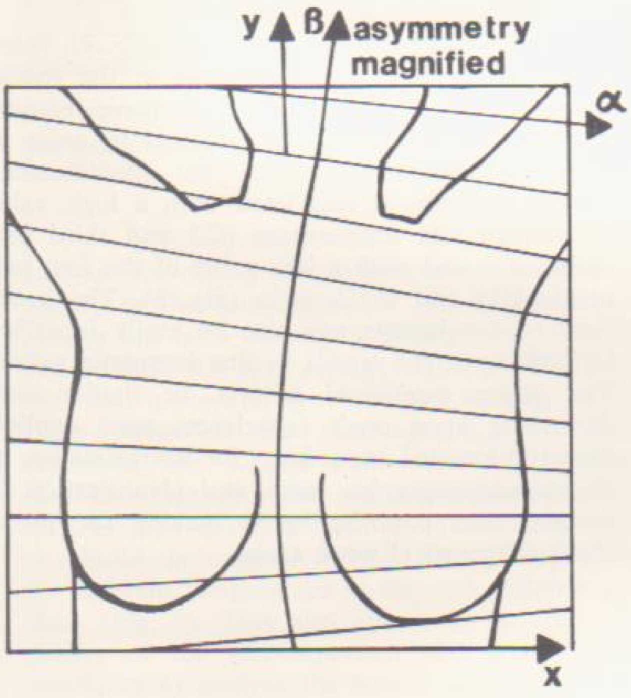
Automation and diagnosis in thermomammography

INTRODUCTION

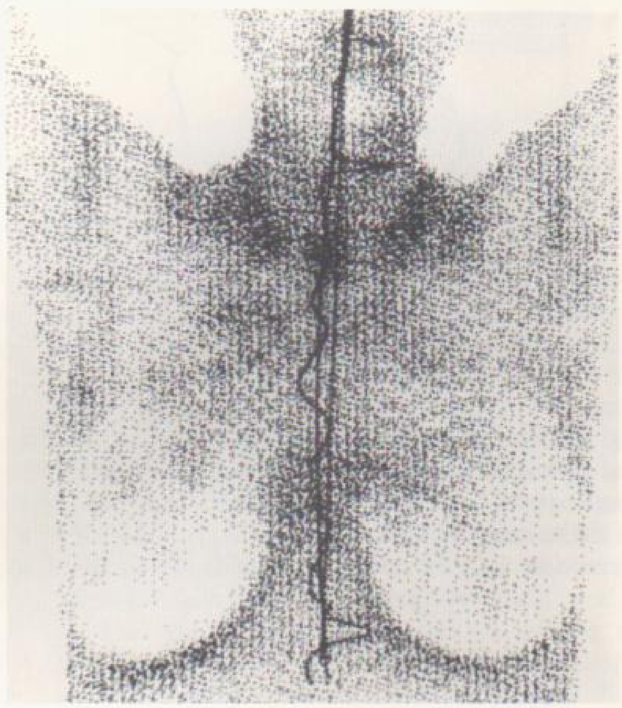
In recent years several factors stimulated a growing interest in the application of computers to the analysis and treatment of thermographic data. Emphasis on mass screening, under due limitations inherent in investigated pathology, requires carefull examination of automation's capabilities to speed up investigation time and to lower the price/efficiency ratio of the diagnostic procedure. The Bioengineering Group of the CNR (National Research Council) CNPM of Milan and of the Institute of Applied Thermodynamics of the Politechnic of Milan in cooperation with the Sanitary Physics Department of the Institute for Investigation and Healing of Tumors in Milan started in 1975 a joint research effort aiming at developing and exploiting automation capabilities in thermomammographic diagnosis. The following steps in research work have been considered and carried out: *a*) collection, digitalization and monitoring of thermographic data; *b*) normalization of thermographic maps; *c*) isothermal line representation; *d*) Fourier analysis of data; *e*) automatic identification of breast positioning. Present efforts are dealing with the following topics: *a*) evidencing of superficial vascularization; *b*) classification of vascular individual patterns; *c*) development of dedicated microcomputer systems for data collection and retrieval; *d*) statistical investigations and follow up of healthy and pathological subjects.

PRESENTATION OF RESULTS

In order to make possible the comparison of maps of different subjects and chiefly to follow the clinical history of a subject, geometrical mispositioning has to be removed from the data. To



A



B

Fig. 1.

accomplish normalization we have assumed a general situation (Fig. 1) in which α and β co-ordinates are determined by optimizing a symmetry descriptor defined as:

$$\Phi = -\{f\ [t=t\ (\alpha,\ \beta)] - f\ [t=t\ (-\alpha,\ \beta)]\}^2$$

Choice of f(t) function is dependent upon stress on computer time or on other considerations; Fig. 2 shows some of the assignable f(t) functions. Rotation analysis can be approached by means of harmonic analysis and phase angle inspection:

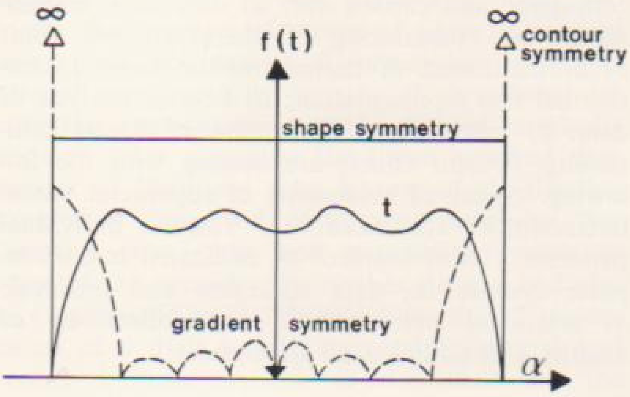


Fig. 2.

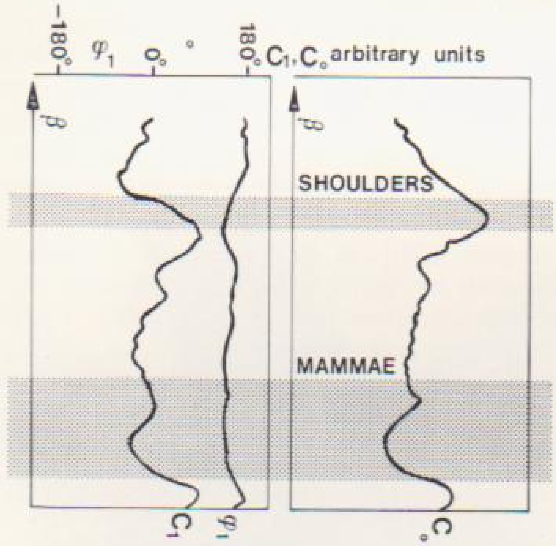


Fig. 3.

Fig. 3 shows the mean value (C_0) line and the first harmonic (C_1) amplitude and phase angle (ϕ_1). Based upon (ϕ_1, ϕ_3, ..., ϕ_{1+2n}) (n integer) data an estimation of body rotation is possible, and a correction may be introduced with the help of a

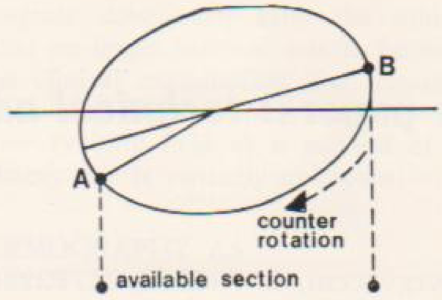


Fig. 4.

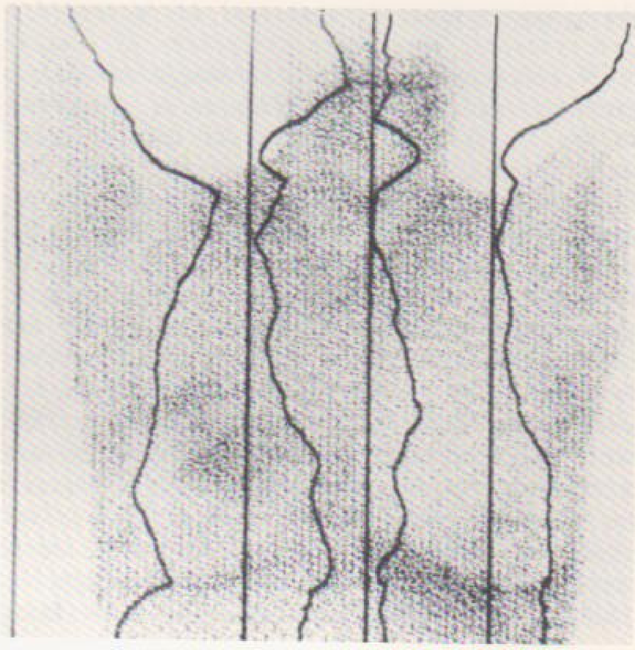


Fig. 5.

spatial model of thorax and breast (Fig. 4). Interesting results have been obtained in the spatial identification of breasts. The harmonic content of line signal has proved significant in order to support quantitative criteria for identification.

Neck position is associated with a high value of average line temperature (C_0) and third harmonic (C_3) and with a low value of the first harmonic (C_1) and C_1/C_0 ratio (Fig. 5). The lower limit of the breasts can also be easily identified by looking at the trends in line harmonic values. The above mentioned criteria, or similar ones depending upon one's experience, seem applicable in automated procedures for normalization of thermomammographic maps and identification of breasts; thus contributing to making the physician's diagnostical work easier.

G. Fava, G. Leonardi, M. Pietrojusti, G. Viganotti, G. Zonca (Milan, Italy)

Breast thermography: an approach to pattern recognition

The need for early diagnosis of breast carcinomas by means of new techniques suitable to mass screening, has determined an increasing interest in the technological possibilities of automatic diagnosis of thermomammograms through a coupling of the thermography with the computer. As first approach to solve this problem we have produced some algorithms for obtaining the automatic recognition of the breasts. They allow us to delimit with precision the areas that must be analyzed to obtain the numerous parameters necessary to the formulation of the diagnosis. The process has been developed through the following basic steps: 1) The voltage signals (video, vertical and horizontal synchronism) making up the video image of the thermograph (Aga Thermovision) are tapped and after A/D conversion they are recorded on a magnetic support such as tape or disk. Printing of data allows us to rebuild the original thermic map distinguishing the different temperature levels with different graphics (Fig. 1). This also allows us to verify the quality of the reconstruction and gives us the possibility to analyze the termic structure characterizing the different thermomammography patterns. 2) The coordinate values outlining the thorax region, from the shoulders to the end of the breasts, and the parameters of the symmetry axes between them, are calculated using, as an evaluation parameter, the typical differences of temperature between the breast and the sternal region. Inside this region, the edges of the breast are reconstructed by applying the matrix elements (raw data introduced into the computer by A/D conversion) to a convolution operation using the Gradient operator. The parameters of the second degree equation (Parabola) better corresponding to the distribution of the points forming the edges of the breast (Fig. 2), are calculated by means of best fit method. 3) All elements of the matrix external to the area included by the two breast parabolas are set to zero, thus obtaining breast isolation (Fig. 3). By means of this technique, once having calculated and memorized all data and parameters concerning the whole thermomammography image, we can concentrate our attention just on the mammary areas and proceed to the analysis and definition of the variables that will set up a function able to descriminate accurately between the class of the thermographically normal cases and that of the doubtful ones.

Fig. 1. Printing of data rebuilding the original thermomammogram; isothermal lines are plotted with different colours.

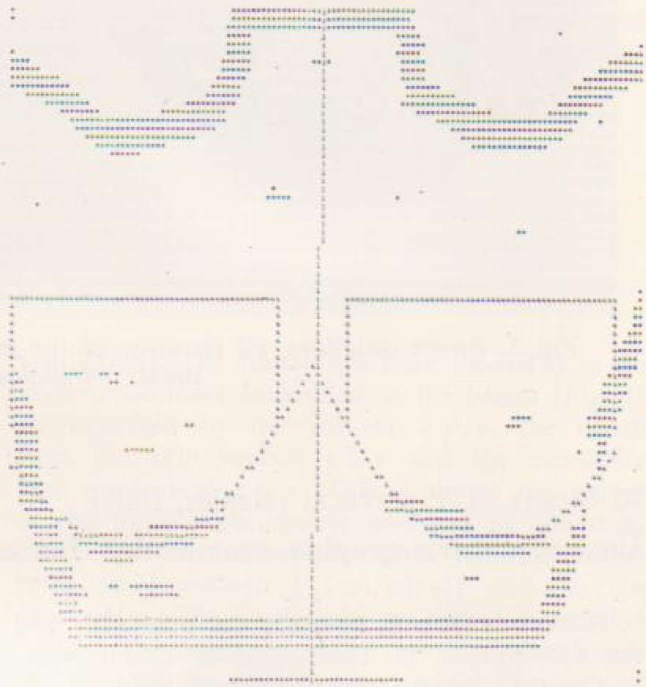


Fig. 2. Gradient matrix: the graphic symbol « 4 » indicates the edges of the breasts.

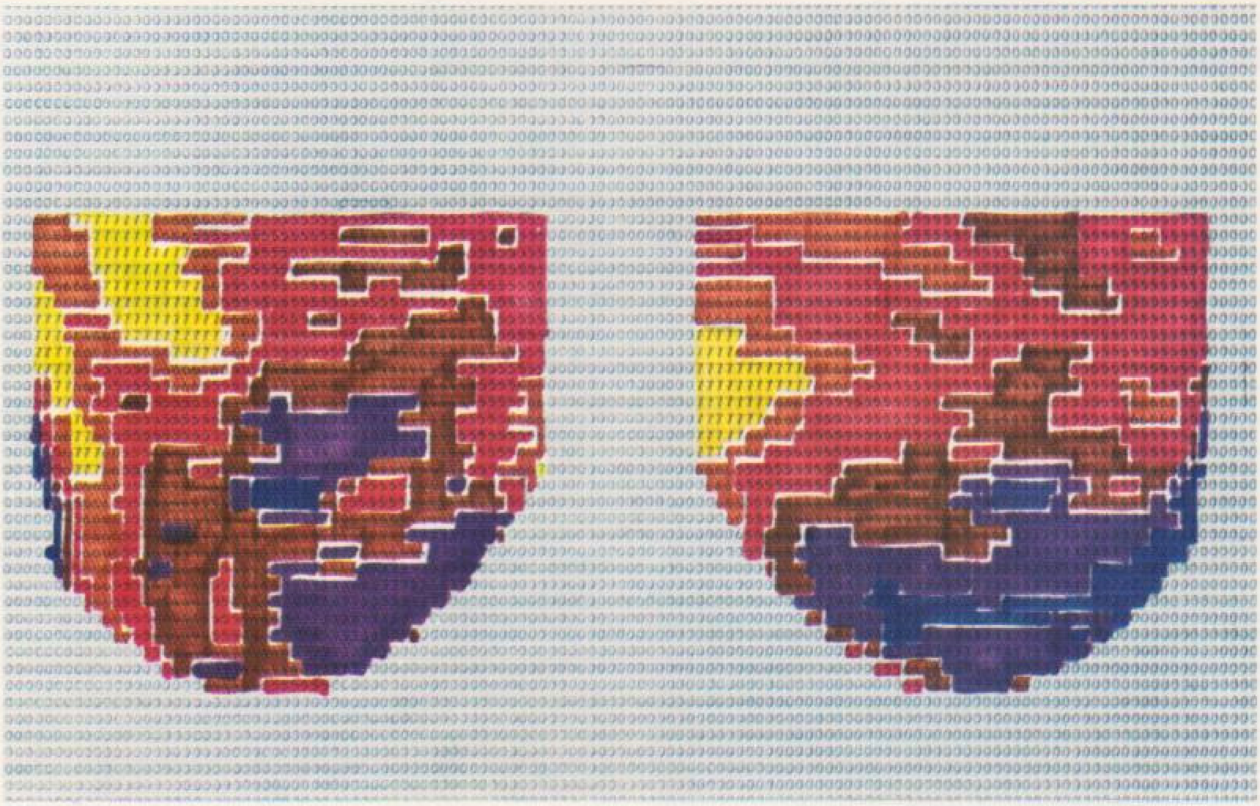


Fig. 3. Breast isolation: all elements of the matrix external to the area included by the two breast parabolas are set to zero.

R. Monti, B. Piscitelli (Naples, Italy)

Unsteady thermographic examination for cancer detection

This study intends to show the possibility and the convenience of thermographic examinations at unsteady thermal conditions and to point out how to utilize, more completely the information provided by thermography for the clinical diagnosis of breast cancer. It is well known that thermography may only give a measure of the skin surface temperature and not of the more interesting deep tissues temperature. Therefore one must try to correlate skin temperature to the cancer characteristic (nature, dimensions, depth, activity). On the other hand the skin temperature distribution depends also on the thermal conditions of the patient during the thermographic exploration (steady or unsteady state). In particular, at steady state (« thermalized » patient), the skin temperature distribution depends on: 1) Thermal and physical properties of the cancer and of the surrounding tissues. 2) Coefficient of heat transfer between skin and environment. 3) Environmental conditions (air temperature and humidity, wall conditions). At present, with the usual thermographic protocols, these conditions are unlikely to be realized; on the other hand unsteady conditions exist at the end of the precooling phase. Thermographic exploration at unsteady conditions is influenced by the temperature evolution rate of the system towards new steady thermal conditions and therefore by the length of time of the observation. A possible « unsteady » protocol can be defined as follows: suppose a quasi-steady state is reached by a prolonged ventilation (corresponding to a heat transfer coefficient h); at these conditions the heat flowing from the deep tissue to the skin equals that flowing from the skin to the environment i.e.:

$$\dot{q} = k \frac{\delta T}{\delta Z} = h \, (T_s - T_a) \qquad (1)$$

suppose that we now stop the ventilation (at $t=0$ we make $h_o=0$ or $h_o \ll h$) we then have unsteady conditions during which skin temperature increases towards new conditions characterized by $h_o=\text{const}$. After $t=0$ the skin gets warmer with a rapidity (measured by $\delta T/\delta t$) proportional to the instantaneous heat flux from the deep tissue to the skin.

In the presence and in the absence of a tumor the time derivative of the skin temperature at the end of the cooling can be related to the heats generated by the tissues ($\dot{Q}$, $\dot{Q}_t$):

$$\left(\frac{\delta T_s}{\delta t}\right)_{t=0} \cong \dot{Q} \qquad \left(\frac{\delta T_{st}}{\delta t}\right)_{t=0} \cong \dot{Q}_t \tag{2}$$

so that the heat produced by the tumor ($\Delta\dot{Q}_t = \dot{Q}_t - \dot{Q}$) can be expressed as:

$$\frac{\Delta\dot{Q}_t}{\dot{Q}} = \frac{\left(\frac{\delta T_{st}}{\delta t}\right)_{t=0}}{\left(\frac{\delta T_s}{\delta t}\right)_{t=0}} - 1 \tag{3}$$

Therefore the detection of the evolution in the skin temperature in correspondance to a hot spot and to a distal area, may yield a measure of the heat produced by neoplastic tissue and may give useful information about cancer dimension and activity. In this way it may also be possible to discriminate between different causes of local temperature differences (for instance between circulatory disturbances, inflammation and cancer): different diseases are characterized by different time trajectories of the skin isotherms. The measurement of the skin temperature time variation is accomplished by taking a number of thermograms at different times, after the precooling phase is terminated, and by analyzing them by means of a computer. The experimental set-up includes an analog-digital converter, a digital mass storage unit and a digital computer for the elaboration of the information and for the presentation of the automatized diagnosis.

R. Monti [1], F. di Marino [1], M. Intaglietta [2], ([1] Naples, Italy; [2] San Diego, USA)

Numerical experiments on the simulation and on the optimization of the protocol for the breast cancer diagnosis

The objective of this work is to ascertain new possibilities for the thermography in the breast cancer diagnosis in order to avoid the typical drawbacks of the present thermographic examinations. A mathematical model of thermal breast behaviour has been set up and the heat conduction equation is solved by the finite element method. A numerical program computes the unsteady temperature distribution in the breast at different ambient conditions (temperature and ventilation). The tumor has been modelled as an asymmetric mass embedded in the breast (Fig. 1) characterized by the volume « V_t », the depth from the skin surface « δ_t » and the metabolic heat production « p_t » (Tab. I shows the values of the tumour parameters analyzed by the computer). All the numerical values reported below refer to $p_t = 60 \times 10^{-4}$ [cal/cm^{3}s]) and to the case « H ». The work tries to define a protocol for the thermographic observation of the breast and to find the conditions at which the tumour is easily detectable by a computer assisted thermograph which provides the skin temperature distributions versus the time.

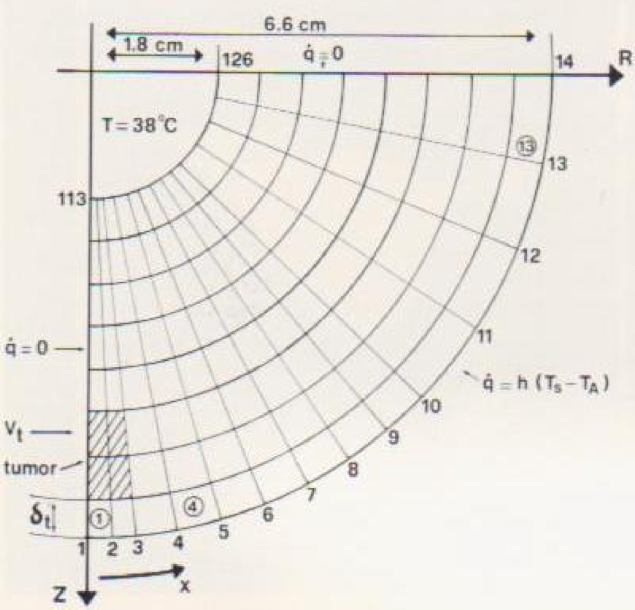


Fig. 1. Asymmetric model of the breast.

The protocol consists of: 1) A precooling phase (so called « thermalization ») when the patient is exposed to a fan blowing air onto the skin for a time « t_r ». The heat transfer coefficient during this phase is « h_r » and is due to both convection and radiation. 2) An observation phase by the thermograph at a reduced heat transfer coefficient (h_{oss}). The thermograms are taken at different times (t_{oss}) after the precooling phase is termined. In these two phases the value $h_{irr} \simeq 1.4\ 10^{-4}$ (cal/cm^2 s°C) is the lowest value that the heat transfer coefficient can attain (which is due to radiation only) and we define:

$$\beta_r = h_r/h_{irr}; \quad \beta_{oss} = h_{oss}/h_{irr}$$

An extensive numerical experimentation has been carried out with different tumours and protocol parameters. The main conclusions which can be drawn are the following ones: *a*) The steady

Tab. I. **Volumes and depths of the analyzed of tumours.**

Case	*Volume* (cm^3)	*Depth* (cm)	*Case*	*Volume* (cm^3)	*Depth* (cm)
A	1.06	0.6	F	0.84	1.2
B	4.25	"	G	3.36	"
C	5.72	"	H	7.52	"
D	8.06	"	I	0.99	"
E	12.80	"	L	11.76	"
			M	17.66	"

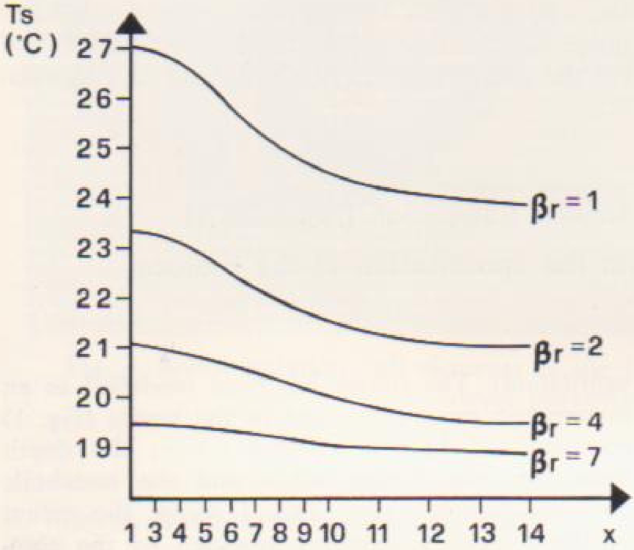


Fig. 2. Steady state skin temperature distribution at different ventilation conditions.

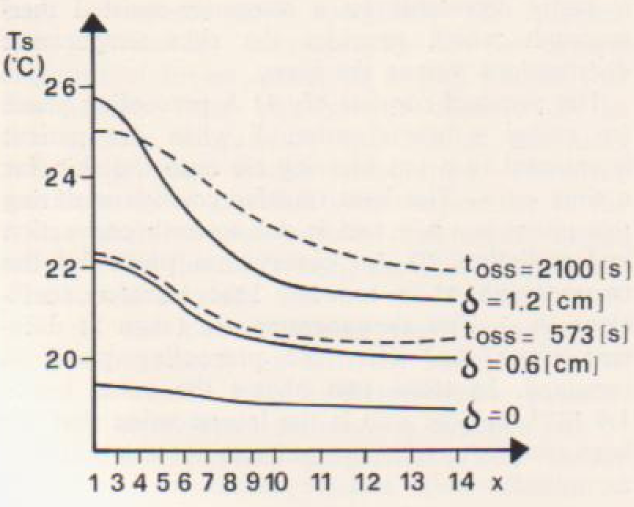


Fig. 3. Internal steady temperature distribution (solid line) corresponding to an intense ventilation ($B_r=7$) at different depths ($\delta=0$; $\delta=0.6$; $\delta=1.2$) compared to the unsteady surface temperature distribution during the observation phase ($\beta_{oss}=1$) at different observation times.

state skin temperature distribution, after the precooling, shows a flat maximum for high β_r. The tumour appears therefore more depctable when β_r is a minimum (i.e. at no ventilations) *b*) Steady conditions, in the precooling phase, are reached only after long time. Precooling times of one hour appear to be still not sufficient for obtaining thermalized conditions. *c*) During the observation, the surface temperature distribution evolves towards the new steady state conditions, characterized by the skin heat transfer coefficient « h_{oss} ». During the « heating up » observation phase the skin temperatures tend the attain values which are similar to the deep tissue values (and therefore more relevant for the tumour detection). It is shown that a correspondence exists between the time of observation and the depth so that the unsteady surface temperature, taken at time « t_{oss} », is similar to the temperature distribution existing in the steady state at a depth « δ » beneath the skin (δ is an increasing function of « t_{oss} ») (Fig. 3). *e*) All the above considerations suggest to follow an unsteady protocol and to

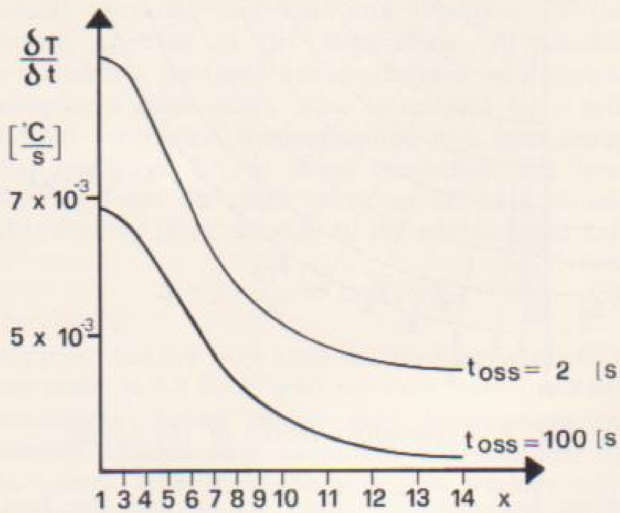


Fig. 4. Surface distribution of the skin temperature time derivative at different observation times ($\beta_{oss}=1$). Initial conditions are thermalized precooling at $\beta_r=7$.

perform the diagnosis taking a number of thermograms after the precooling (when the surface temperature changes rather rapidly). *f)* The time and space derivative of the skin temperature at the tumour location is a very sensitive parameter for the tumour detection without the necessity of referring to the temperature of the controlateral area. The time derivative of the surface temperature ($\delta T/\delta t$) can be measured by a computer assisted thermograph (Fig. 4). The location of the neoplasm is easily detected also for relatively small and deep tumours. *g)* Similar numerical analyses are being performed for a precooling phase realized by means of a liquid-cooled brassiere which is at the moment being tested in USA. In conclusion the present analysis supports an automatized breast cancer diagnosis method which may avoid the difficulties associated with the evaluation, by eye, of the presence of the tumour.

Experimental thermography

B. Talia, V. Sonnino, P. Angiari, F. Romani, P. L. Trevisan,
E. Belluzzi, G. Masetti (Modena, Italy)

Intraoperative neurosurgical applications of telethermography: first results in the rabbit

The effect of arterial ligation on the cerebral blood flow was studied in anesthetized rabbits by means of an AGA 680 Thermograph with a 15°×15° lens and an extensor ring. The experiment was conducted in an airconditioned room at 21°C. Ten rabbits underwent hemicraniectomy. Two of these had a bilateral craniectomy to allow a comparative study of the two cerebral hemispheres. Three control rabbits were studied to evaluate temperature variations of the cerebral parenchima after removal of the bone flap. After an initial temperature drop of about 2°C, which took place within the first half hour, readings remained stable throughout the remainder of the experiment. The left common carotid artery was closed in three rabbits, and the median cerebral artery was closed in three more rabbits. A cortical trauma was induced in the tenth rabbit. Histoche-

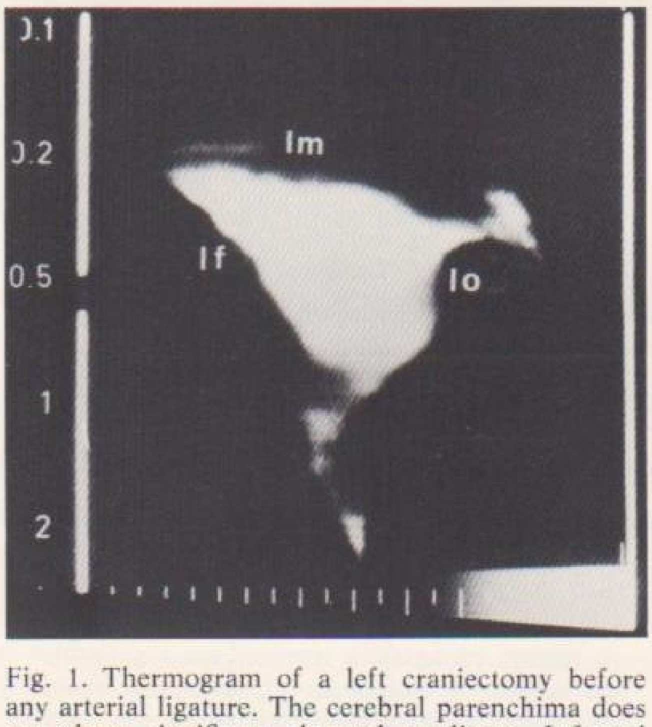


Fig. 1. Thermogram of a left craniectomy before any arterial ligature. The cerebral parenchima does not show significant thermal gradients. Infrared output is homogeneous throughout the area. Axial view.

lm = Median line on vertex. lf = Frontal line. lo = Occipital line.

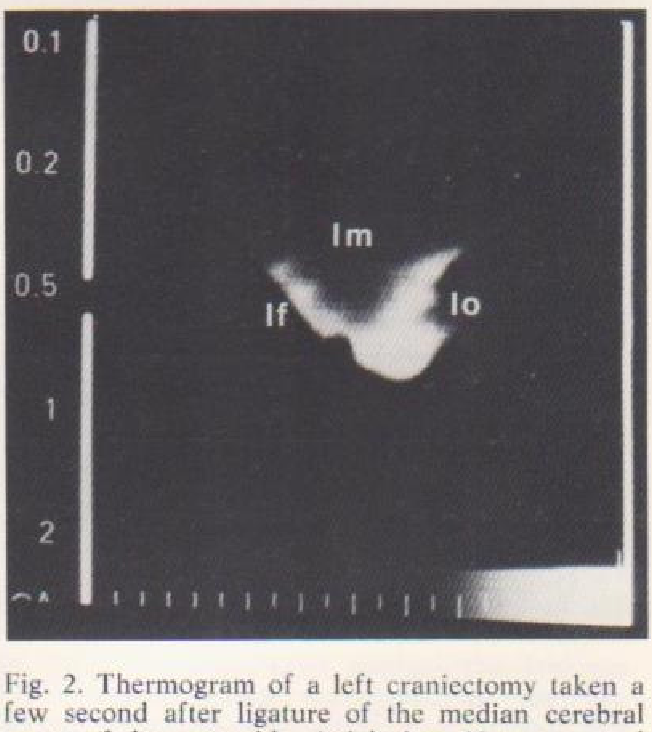


Fig. 2. Thermogram of a left craniectomy taken a few second after ligature of the median cerebral artery of the same side. Axial view. Note a central rounded hypothermic area, in the territory normally supplied by branches of that artery. The temperature difference was about 2°C as compared to the remaining parenchima (white area). Landmarks same as in the previous figure.

mical assays were obtained from the ischemic parenchima as well as from normal parenchima.

RESULTS

Thermographic readings prior to arterial ligation revealed a homogeneous caloric output from the cerebral parenchima (Fig. 1). The borders of the bone flap were hypothermic by about 2-3°C. The monolateral ligature of the left common carotid artery caused an immediate hypothermic variation of the cerebral parenchima. This is clearly evident in the rabbits with bilateral craniectomy, where the ipsilateral parenchima is about 4-5°C below the controlateral side. The ligature of the median cerebral artery caused a central rounded hypothermic area, which was about 2°C colder than the surrounding parenchima (Fig. 2). The cortical trauma revealed an immediate hypothermic change of about 5°C, which did not vary even after repeated follow-up controls. Laboratory findings confirmed ischemia of the ipsilateral parenchima, with cellular degeneration, which in some cases was irreversible. In this study telethermography proved capable of evaluating rapidly and with good precision the thermal variations of the cerebral parenchima after arterial ligature. In the Authors opinion this method can also offer an indication of the extent of the ischemic lesions. Further studies will be necessary for a better evaluation of these data.

Head and neck

G. Cennamo, P. Rocco, G. Greco, G. Bonavolontà (Naples, Italy)

Thermography of tumours of the orbit, of the ocular globe, and its parts

In the period 1975-76 we subjected to facial thermography 30 patients affected by hystologically determined space occupying lesions of the ocular bulb and orbit. We used an AGA Termovision, model 680. Each patient was prepared for the examination by keeping him stationary for about 15 minutes in a room at constant temperature (at 22-23°C), and before a ventilator for about 10 minutes. The patients examined were divided into two groups: in the first group were included the patients who were thermographically negative (thermal gradient less not more than +1°C relative to the corresponding contralateral area). In the positive cases the ocular or orbitary lesion presented thermal gradient which was more than 1°C (Tab. I).

Our data partly supports the data which already exists in the literature. The benign tumours are cold, as the endocrine exophthalmias which we have not included in our study. Inflammation, most of the malignant tumours, and tumours of the blood vessels are warm. The thermal gradient

Tab. I. **Thermographic results of 30 cases with ocular and orbital tumours, confirmed hystologically.**

Location	*Type of space occupying lesions*	*No. cases*	*Thermography* –	*Thermography* +
Conjunctiva	Malignant melanoma	2		2
Uvea	Malignant melanoma of the choroid	6	4	2
Retina	Retinoblastoma	3	1	2
Orbit	Meningioma	4	4	
	Mucocele	3		3
	Pseudo-Tumours	2	1	1
	Cysts	3	3	
	Neurofibromas	2	2	
	Dacryoadenitis	2		2
	Capillary hemangioma	1		1
	Cavernous hemangioma	1		1
	Leiomyoma	1	1	
	Total	30	16	14

of these patients in most cases has been greater than +2.5°C. In the tumours of the blood vessels and in the acute inflammatory processes the hyperthermic area appeared with sharp limits (Fig. 1); on the contrary, in the malignant tumours, the entire orbit is hyperthermic. In one of our cases, were thermographically positive, with a difference of temperature not greater than 1.5°C. That could depend, in our opinion, on phenomena of necrosis in these tumours, or on the particular location of the tumour.

In conclusion, we mantain that thermography

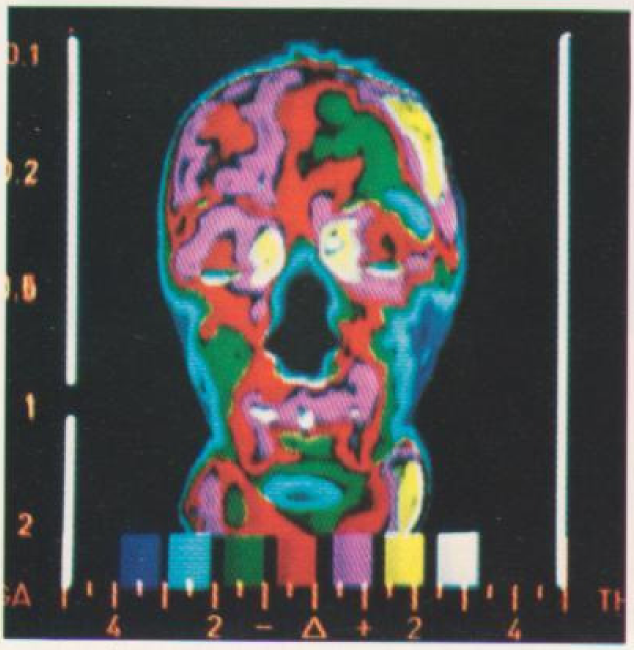


Fig. 1. Right dacryoadenitis in 21 year old woman. Hyperthermic area with sharp edges ($\Delta t = +2°C$) in the upper external angle.

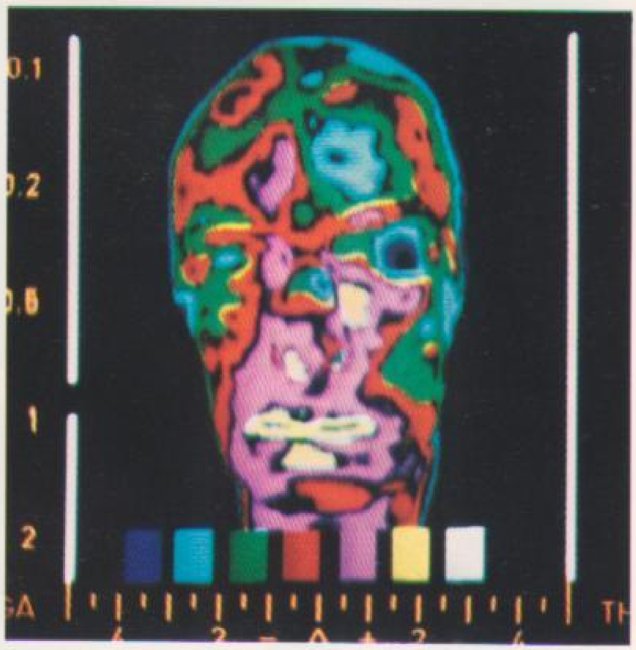


Fig. 2. Left orbital meningioma with intra-cranial extension in a 53 year old man. The left orbit is highly hypothermic ($\Delta t = -4°C$).

a malignant melanoma of the conjuntiva, the tumour was hypothermic, probably in relation to the necrosis of the tumour. In 4 cases of monolateral exophthalmia due to intraorbital meningiomas, we have observed a clear hypothermia of the orbit affected. That does not agree with the results of other investigators (Fig. 2). In 6 cases of malignant melanoma of the choroid, only 2

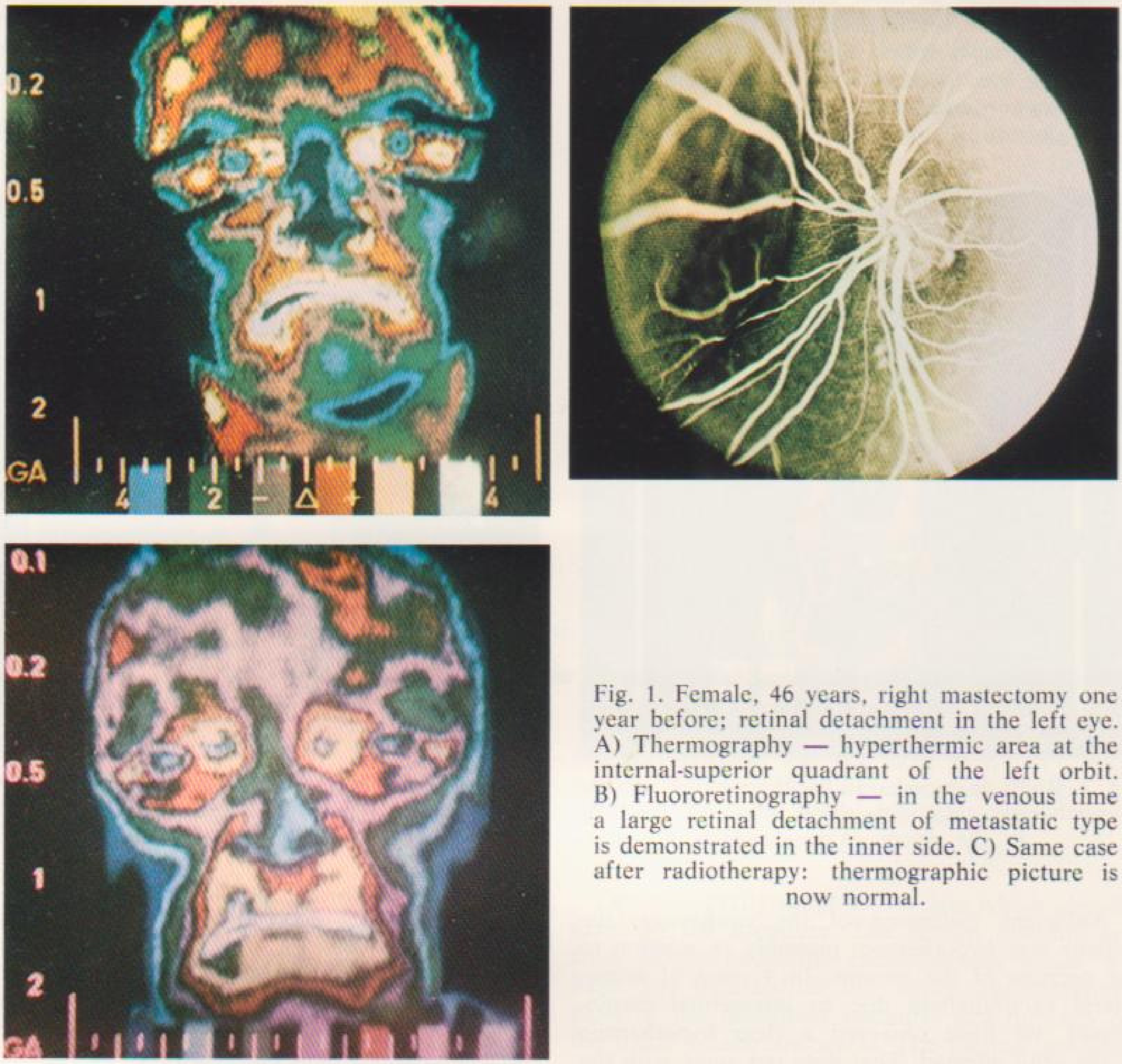
may be useful as a complementary diagnostic technique. Particularly, we maintain that such examinations are just as useful in the periodic post-operative or post-radiation check-ups in the malignant tumours, because of the innocuousness of the examinations, and the possibility of repeating them.

G. P. Ausili-Cefaro, V. Ciarniello, M. Borgioli, U. Volpi (Rome, Italy)

Thermography and fluorescent retinic angiography in the evaluation of eye metastasis

Recently, in co-operation with the UCSC Institute of Ophthalmology we had the opportunity of following some patients affected by retinal detachment secondary to metastasis of breast carcinoma. We employed both thermography and retinic fluorescent angiography in those cases of secondary detachment where the dioptrics allowed the fulfilment of both investigations. The thermography was carried out with the AGA thermograph, mod. 680, in a room at constant temperature and humidity in order to be able to perform control exams repeatedly. We employed, for the fluororetinographic method, the Topcnon T.R.C.F.$_3$ high speed retinograph of the two Optical Company. The association of the two methods allowed us to demonstrate the efficacy of the radiochemiotherapy employed for the treatment of these patients. The thermographic pattern seen before the treatment showed a clear thermic asymmetry of the upper-internal angles of

A



B

C

Fig. 1. Female, 46 years, right mastectomy one year before; retinal detachment in the left eye. A) Thermography — hyperthermic area at the internal-superior quadrant of the left orbit. B) Fluororetinography — in the venous time a large retinal detachment of metastatic type is demonstrated in the inner side. C) Same case after radiotherapy: thermographic picture is now normal.

the orbits. The fluororetinographic pattern showed the presence of a secondary retinal detachment that was homogeneously imbued by colouring (Fig. 1). The thermographic control performed after radiochemotherapy showed a thermic symmetry of the upper internal orbit angles (Fig. 2). In the same way, the fluororetinographic control exam indicated the resolution of the retinic lifting process with modified areas of pigmentated epithelium and the presence of some dark chorioretinic streaks due to sclerotic retraction. In conclusion, the association of the two methods allows us to follow the evolution of the treated lesion and program the correct therapy in case of relapse.

C. de Renzis, G. la Vecchia, G. Pastore, D. Salvo (Rome, Italy)

Thermography and radioisotope scanning in the study of thyroid pathology

The superficial position and the rich vascularization of the thyroid could permit a reliable thermographic approach. However, the literature gives some rather contrasting opinions on the efficacy of the method. For some time we have associated the thermographic investigation with radioisotopic scanning using I^{131} or Tc^{99m}, especially for differential diagnosis in patients with solitary nodules of doubtful nature. We tested, by the two methods, more than 180 patients. In 51 of these solitary nodules, we had histological control exams that were compared with the thermographic data (Tab. I). In 16 cases of functioning adenoma with high uptake rates at scanning, 13 showed hyperthermic patterns, while the other 3 showed the presence of a thermographically cold area at the adenoma site. We observed, in the normal up-take simple goiters, in the cystic-colloid ones and in those presenting micro and medium follicular adenoma zones, uncertain results that can not be classified. For the neoplastic and cystic forms presenting low uptake areas at scanning, the thermographic investigation showed itself to be decisive. In fact, all 7 patients with neoplasias showed, at the thermographic test, patterns of hyperthermia; opposite, 17 of the 19 patients with cystic formations showed hypothermic patterns, while the remainig 2 cases did not present any substantial thermic modification. We believe it right to point out some limitations of the method: *a*) difficulty in showing formations under 2 cm; *b*) difficulty in showing formations extending under the jugular; *c*) difficulty in showing alterations next to the large vessels of the neck and marginal zones covered by sterno-cleidomastoids. In conclusion, in spite of limitations above stated, the association of the two methods (radioisotopic and thermographic) shows itself to be particularly useful in the differential diagnosis of the « low uptake nodule ».

Tab. I. **Thermographic data in 51 histologically confirmed solitary nodules of thyroid.**

Skin temperature	Hyper-thermic	Functioning adenomas	N. 13
		Carcinomas	N. 7
		Adenomas	N. 1
	Normo-thermic	Adenomas	N. 3
		Localized hyperplasias	N. 1
		Cysts	N. 2
	Hypo-thermic	Adenomas	N. 4
		Functioning adenomas	N. 3
		Cysts	N. 17

L. Verzini, F. Romani, B. Talia (Modena, Italy)

Results of telethermographic applications in E.N.T.

We have searched for T.T.G. applications in the E.N.T. field, and we have expanded our studies beyond salivary pathology to include laryngeal and cervical-facial pathology. Seventy-one patients (Tab. I) with E.N.T. pathology were studied with an Aga Thermovision 680 SET. In order to differentiate the lesions we use the method of thermal comparisons between the clinically interesting areas and the surrounding areas, making symmetrical comparisons as well. With sali-

Tab. I. **Location of pathology.**

Region	*No. cases*
1) Salivar glands	23
2) Cervical facial area	22
3) Larynx	26
Total	71

Tab. II. **Salivar glands.**

No. cases	*Thermographic data*	*Clinical data*	*Byoptic or surgical data*
14	Hyperthermia	Parotid or submaxillary masses	6 - Cancers 4 - Mixed tumours 4 - Acute flogistic processes
8	Normothermia	Parotid masses	1 - Simple hypertrophia 7 - Chronic parotitis
1	Hypothermia	Parotid mass	1 - Cholesterinic granuloma

Tab. III. **Cervical-facial area.**

No. cases	*Thermographic data*	*Clinical data*		*Byoptic or surgical data*	
14	Hyperthermia	8	Latero-cervical or facial masses	4 4	Cancers Benign tumours
		1	Oral floor mass	1	Cancer
		5	Aching and blushing masses	5	Acute phlogosis
4	Normothermia	4	Masses	1 1 2	Latero-cervical metastases Lipoma Cysts
4	Hypothermia	4	Well limited cervical facial masses	4	Cysts

vary pathology (Tab. II) we had a clear thermal increase in cases of neoplasms and acute inflammatory processes. Hypo- and normo-thermal responses in our cases are connected with chronic inflammatory processes. Also, in the field of cervical-facial pathology (Tab. III), we have observed hyperthermic data connected with acute inflammatory processes or neoplasms. We have observed that hypothermal areas are very important when they have oval borders. In such cases the clinical exam has always shown the presence of a cystic lesion. Thermography has thus shown itself to be very useful in the differential diagnosis of anterior cervical tumefactions. Thermography was erroneously negative only in one very deep latero-cervical metastatic localization. The observation of laringeal pathology (Tab. IV) was made easy by the presence of air inside the larynx. Hyperthermal responses were closely related to the clinical verification of primitive cancers or latero-cervical metastasis. Hypothermal latero-cervical and extra-laryngeal areas were correlated with verified laryngoceles. We can thus conclude that T.T.G. is particularly indicated in the laryngeal field as it permits one to establish: *a*) early diagnosis of local relapse; *b*) pre-operative diagnosis of local metastasis; *c*) post-operative controls at short and long term.

Tab. IV. **Larynx.**

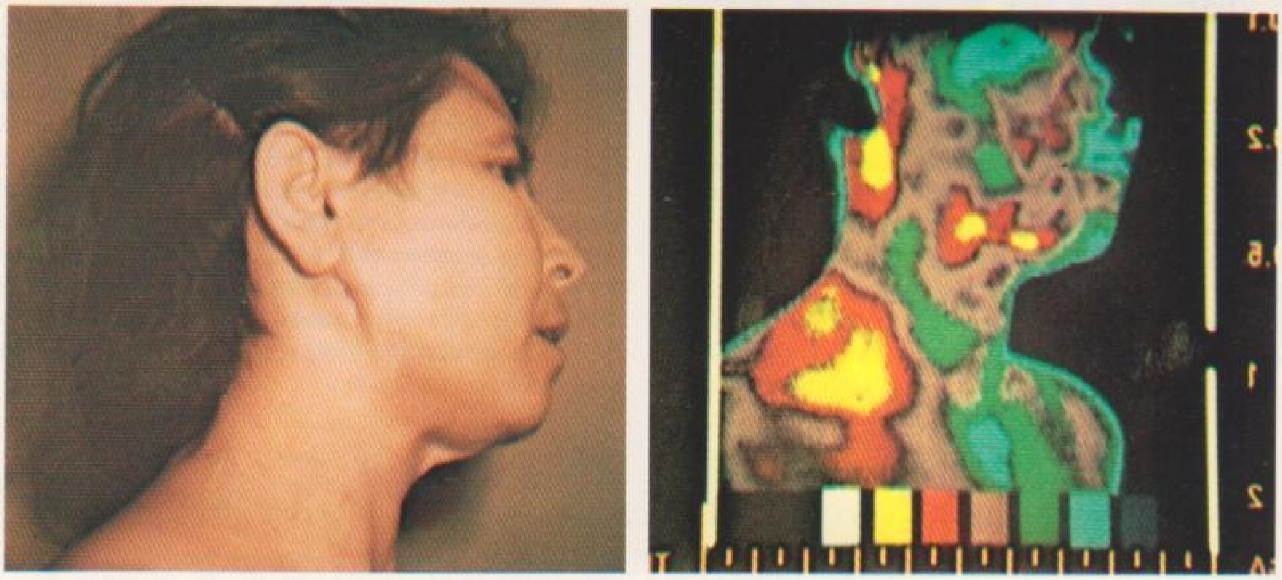
No. cases	*Thermographic data*	*Clinical data*		*Byoptic or surgical data*	
32	Hyperthermia	18	Laryngeal tumours	18	Cancers
		11	Latero-cervical masses	{ 10 { 1	Laryngeal metastasis Reactive lynphoadenitis
		3	Peristhomial infiltration	3	Cancer recurrences
2	Hypothermia	2	Vestibular laryngeal masses	2	Laryngoceles

V. Ciarniello, L. Trodella, G. David, V. Modica (Rome, Italy)

Thermography in E.N.T. pathology

For about three years, in co-operation with the E.N.T. Institute, we tested thermographically some patients having either inflammatory or neoplastic lesions involving head and neck. The thermographic pictures were taken in a room at costant temperature and humidity by an AGA THV device. We thought it right to choose two cases of higher and particular interest. The first case concerns a 48 year old woman presenting a soft, aching and fistulous swelling of the left hemimandible involving the angular region (Fig. 1 *A*). Thermography showed a hyperthermic area in this region and, furthermore, an asymmetric area with a high thermal gradient involving the orizontal branch of the homolateral hemimandible (Fig. 1 B). The thermographic report was confirm-

A

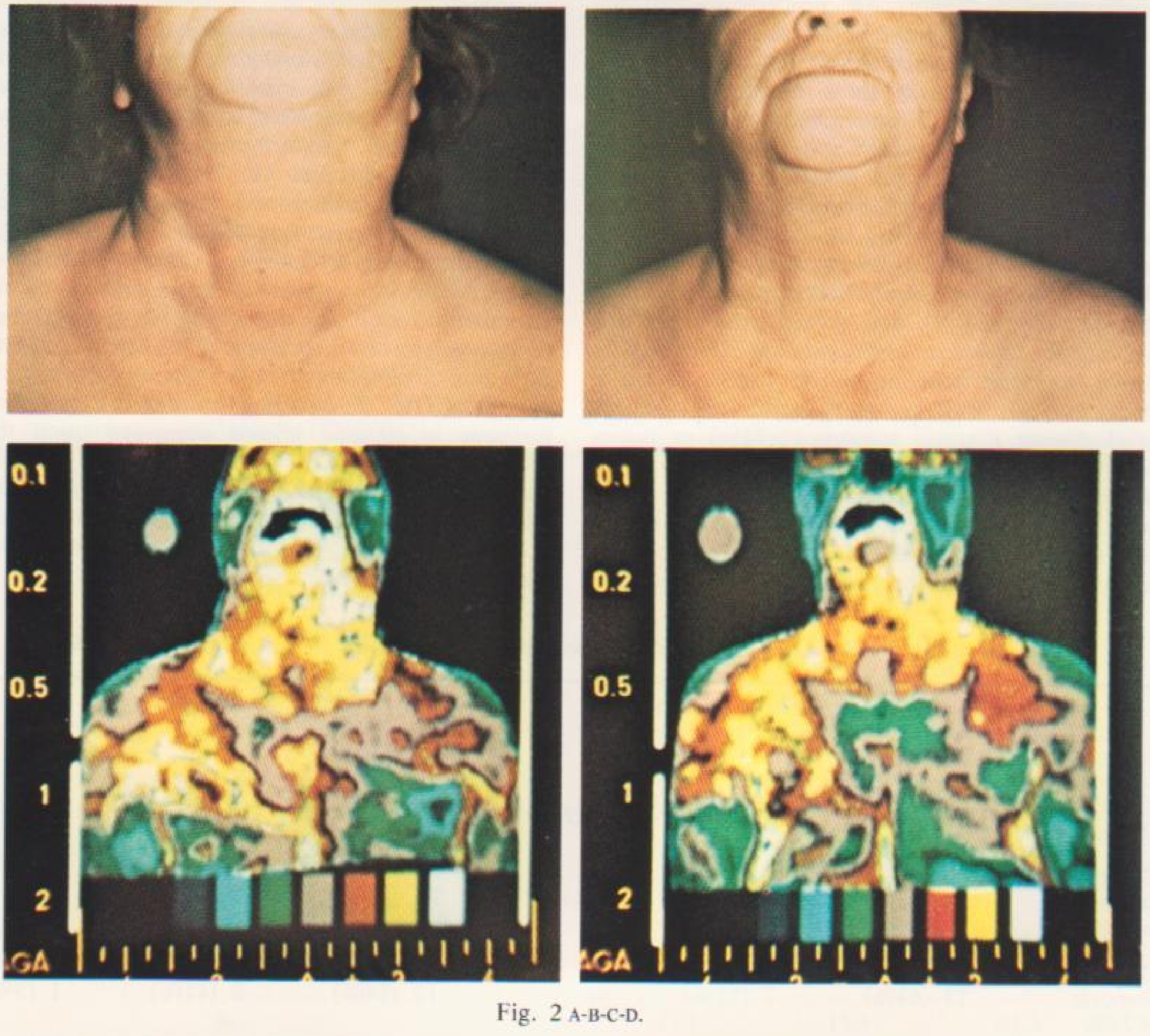


B

Fig. 1 A-B.

A

C



B

D

Fig. 2 A-B-C-D.

ed by radiographs that showed a large osteolitic zone with bone sequestrum which was subjectively and objectively silent. The second case concerns a 56 year old woman admitted into hospital for successive crises of dyspnea. The clinical investigation showed a remarkable left cervical tumefaction (Fig. 2 A) compressing the upper respiratory organs: a lymphnode biopsy ascertained a probable tonsillar anaplastic carcinoma. Thermography in the frontal view showed a large hyperthermic area, more evident on the left side of the neck expanding downward to the upper clavicular homolateral region (Fig. 2 B). Because of the histological type of the neoplasia, a chemoradiotherapeutic association was programmed. The thermographic control carried out soon after chemotherapy showed a size reduction of hyperthermic area on the left side of the neck (Fig. 2 D) according to metastasis decrease (Fig. 2 C). The patient was then treated with tele-cobalt-therapy by the « neck bath » technique. In conclusion, thermography carried out on patients with inflammatory and neoplastic processes is an important diagnostic element in the evaluation of the lesion and programming when and how to accomplish further treatment.

B. Talia, F. Romani, M. S. Saviano, E. Belluzzi, G. Tuscano (Modena, Italy)

Noninvasive instrumental methods for the diagnosis of cerebral vascular insufficiency

Surgical reconstruction of stenotic lesions in the extracranial cerebral vascular circulation has become accepted therapy for properly chosen patients with cerebro-vascular insufficiency (C.V.I.) syndromes. Such a therapeutic possibility has increased the interest in those investigations that are necessary both for the screening of the patients to submit to angiography and then to surgical intervention, and for the control of the therapy employed. The object of this work is the evaluation of the two non invasive methods more frequently used in this field: thermography and Doppler ultrasonic examination. A directional Doppler (Parks 806) and Aga Termovision 680 were used to screen 103 patients with C.V.I., stroke, transient ischemic attack, and/or asymptomatic carotid bruit in cases with occlusive arterial disease. Carotid stenosis (>75%) or occlusion was manifested by: reversed frontal artery (a more reliable branch of the ophthalmic artery than the supraorbital artery) flow from extracranial collateral branches of the external carotid artery, identified by the test of transient common carotid compression. The thermographic picture consists in: *a*) cold internal supraorbital triangle, *b*) frontal upper external hyperthermia, *c*) sometimes hypothermia of internal orbital angle. For thermographic purposes temperature differences higher than 1°C are considered; lower thermal gradients have only been considered as a suspicious indication. Angiography was performed in 75 cases: vascular lesions (15 occlusions and 47 stenoses) have been found in 62 vessels of 58 patients. In occlusive disease the diagnostic value of thermography was 86%, 1 false negative occurred (7%) for an occlusion of a common carotid artery and 1 dubious case (7%) for the presence of a controlateral stenosis. The Doppler exam had only 1 dubious case (occlusion of common carotid). The diagnostic accuracy of the two methods in stenotic lesions depended upon the degree of the stenosis. Thermography in fact did not detect 12% of the cases with stenosis >75%, whereas the percentage of error greatly increased in stenosis <75%. The Doppler diagnostic inaccuracy was even more significant (Tab. I).

Tab. I. **Results of comparison between Thermography and Doppler in the diagnosis of C.V.I.**

	Thermography			*Doppler*		
	+	−	?	+	−	?
Carotid Occlusion	13 (86%)	1 (7%)	1 (7%)	14 (93%)	—	1 (7%)
Carotid Stenosis >75%	22 (88%)	2 (8%)	1 (4%)	21 (84%)	4 (16%)	—
Carotid Stenosis <75%	15 (69%)	7 (31%)	—	12 (54%)	9 (41%)	1 (5%)

To summarise, if on the one hand the data confirm the usefulness of such methods, on the other hand they do not show deep diagnostic differences between them (even if for less significant stenosis thermography is to be preferred). The value of these methods is considerable and they can be used as screening before angiography and also as control of the usefullness and duration of surgical treatment. The limits shown by our study are constituted by: the sub opthalmic lesions, indirect exploration, the fact that these methods are only dynamic and not anatomic, bilateral lesions, lesions with only modest stenosis, long dated occlusions and endocranial lesions. The advantages are: that they are non invasive, atraumatic, without contraindications, very rapid to perform and cheap. We therefore feel that such methods, alone, or better still if associated, can be usefully employed to screen suspicious cases of C.V.I. even if they cannot detect the position and extension of the occlusive process: such information will be obtained later with angiography which may be justified by thermographic and/or ultrasonic data.

Breast diseases

C. di Maggio, A. di Bello, L. Pescarini, R. Dus (Padua, Italy)

Usefulness of thermography in the diagnosis of lobular carcinoma of the breast

We tried to evaluate the findings of thermography in the diagnosis of the in situ and infiltrating forms of lobular carcinoma of the breast. From 1970 to 1975 we found 2 lobular carcinomas in situ (SLC) and 9 infiltrating lobular carcinomas (ILC); 2 patients presented bilateral lesions, therefore we considered 13 cases of lobular carcinoma. In table I we summarized the thermographic findings classified according to Amalric and Spitalier. We obtained a positive report in 61.5% of the cases and a dubious one in 15.4%, so thermography alone gave a correct report in 76.9% of all the cases. In table II we summarized the mammographic and thermographic reports. Intentionally, we did not evaluate the clinical data through they are essential for the final diagnosis. Mammography gaves a negative report in 3 patients (2 affected with SLC and 1 with ILC), a dubious report in the right affected breast of a patient (N. 10) with bilateral ILC; mammography reveled a blurred and spiculated mass, sometimes, with micro-calcifications and skin thickenings. Thermography showed a pathologic process in cases n. 1, 2 and 3 where mammography gave a negative report, thus deciding for the surgical operation. As mammography allowed a correct diagnosis in

Tab. I. **Thermographic findings in lobular carcinoma of the breast.**

No. cases	*Hystol. type*	*Side*	*Thermographic classes*		
			TH1-TH2	*TH3*	*TH4-TH5*
1	SLC	L		+	
2	SLC	R			+
3	ILC	R			+
4	ILC	L			+
5	ILC	R			+
6	ILC	R			+
7	ILC	R	+		
8	ILC	R			+
9	ILC	R	+		
10 }	ILC	R	+		
11 }		L			+
12 }	ILC	L			+
13 }		R		+	
%			23.1	15.4	61.5

69.2% of the cases, and with thermography che correct diagnoses reached the 92% the association of the methods is really important. In conclusion we can say that only the histologist can diagnose a lobular carcinoma; all radiological and instrumental methods can only show the definite or dubious presence of a neoplasm. Mammography has a primary diagnostic importance due to the abundance of data it furnishes. Therefore in the cases with a characteristic mammographical picture, tumoral hyperthermia is diagnostically irrelevant. On the contrary thermography is necessary when its positive report completes an insufficient mammographic picture. Therefore we cannot leave out one or the other of the two methods, because each of them gives its individual contribution to the diagnosis.

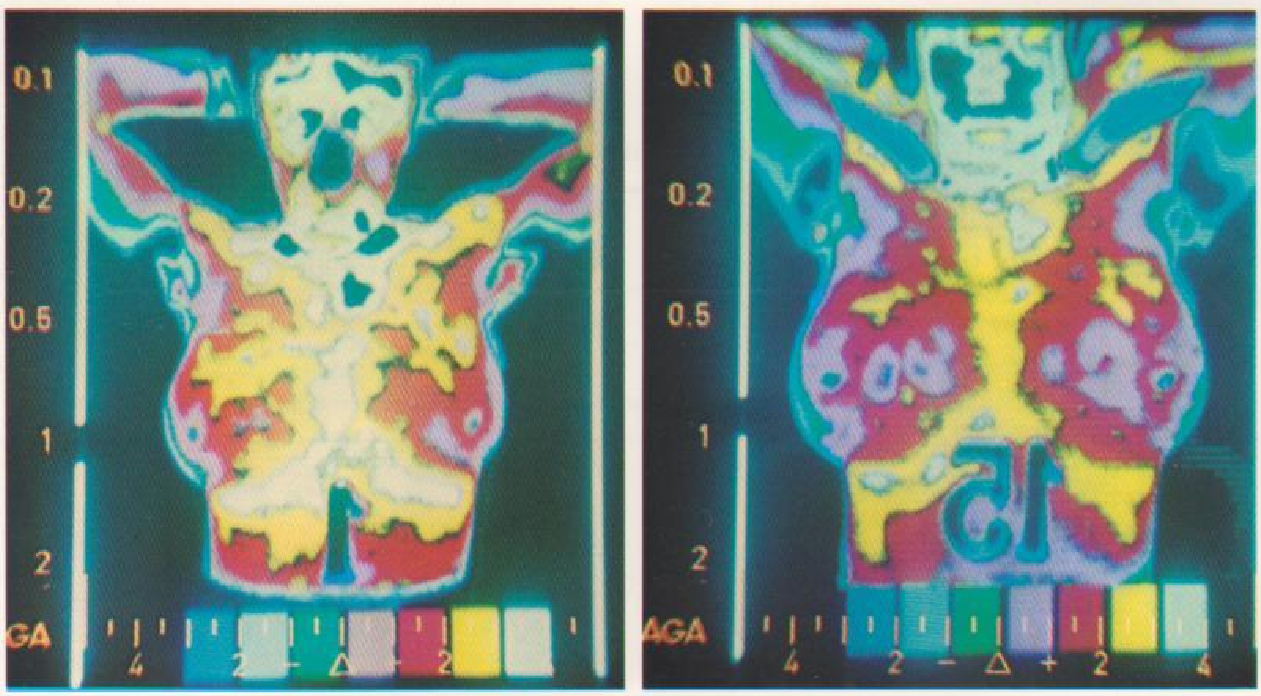
Tab. II. **Summary of instrumental diagnostic methods in lobular carcinoma of the breast.**

		Mammog.	*Thermog.*	*Diagn. trend*
1	SLC	– –	+	+
2	SLC	– –	+ +	+ +
3	ILC	– –	+ +	+ +
4	ILC	– +	+ +	+ +
5	ILC	+ +	+ +	+ +
6	ILC	+ +	+ +	+ +
7	ILC	+ +	–	+ +
8	ILC	+ +	+ +	+ +
9	ILC	+ +	–	+ +
10	ILC	+ –	–	–
11	ILC	+ +	+ +	+ +
12	ILC	+ +	+	+ +
13	ILC	+ +	+ +	+ +

L. Fogher (Trieste, Italy)

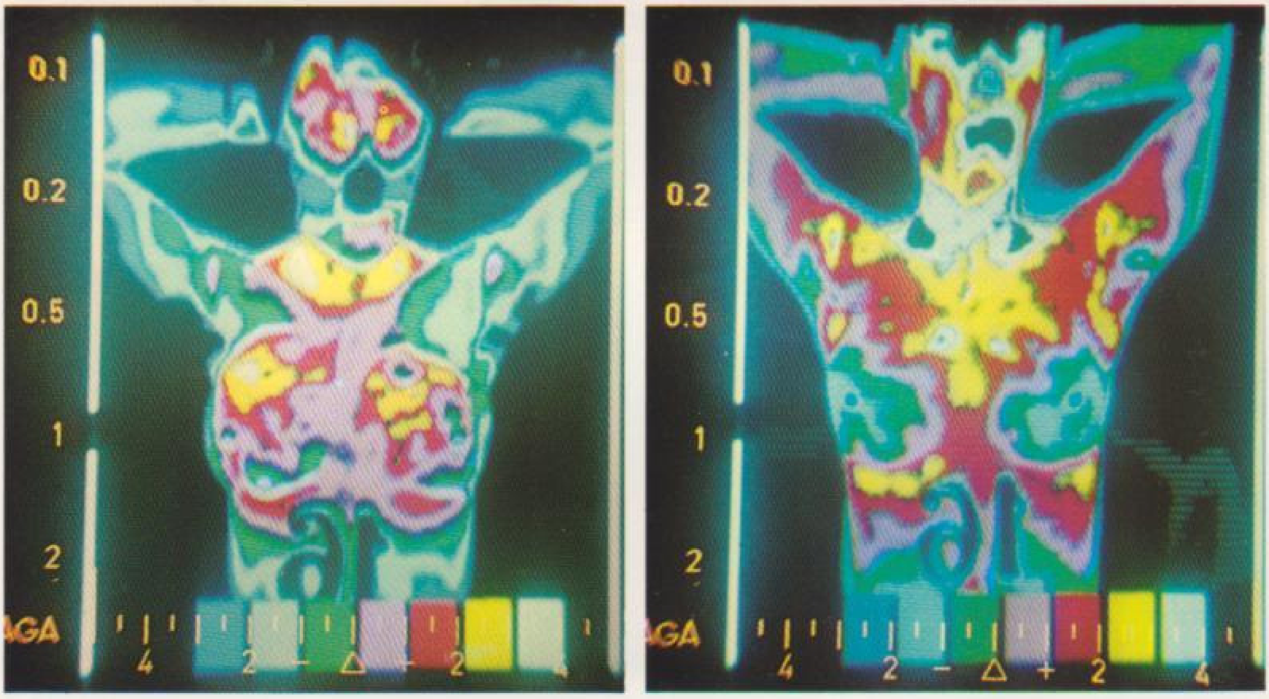
Thermography in ethynodiolodiacetate therapy of fibrocystic mastopathia

Thermography was utilized for serial controls in 106 patients (average age 39 years) affected by fibrocystic mastopathy and treated with ethynodiolodiacetate (Luteonorm). The following method was used: 1) A standard thermogram at 15[th] day from the beginning of menstruation. 2) Ad-



A B

Fig. 1. S. G., 37 years old. Fibrocystic mastophatia. A) Standard thermogram: remarkable bilateral accentuation of the vascular pattern. B) Control at 8[th] month: good reduction of vascular pattern is visible.



A B

Fig. 2. R. G., 39 years old. Fibrocystic mastopathia. A) Standard thermogram: remarkable bilateral accentuation of the vascular pattern. B) Control at 8th month: good reduction of previous vascular pattern.

Tab. I. **Thermography in the first control after ethynodiolodiacetate therapy.**

Thermographic pattern	*No. case*	*%*	
Improvement (+)	47	44.33	57.53
Good improvement (++)	14	13.20	
No improvement	27	25.47	42.47
Worsening	18	17	

ministration of two 2 mg pills of ethynodiolodiacetate per day from the 16th to the 25th day for the next 3 menstrual cycles. 3) Thermographic controls at 1, 8 and 12 months after the end of the treatment. At the first thermographic control, the breast pattern was as in table I.

It thus seems evident that thermographic control is a good means of evaluation of therapy effectiveness.

Osteo-articular diseases

G. LA VECCHIA, G. PASTORE, L. DE PALMA, F. GRECO (Rome, Italy)

Thermographic monitoring of calcitonine therapy in patients with Paget's disease

Paget's disease lends itself well to thermographic investigation owing to the particular characteristics of the pagetic bone, seat of an intense metabolic activity and of an increased hemodynamic condition. For this reason, we wanted to combine this modern method with the hematochemical and radiological tests already employed for quite a long time. The radiological tests, in particular, cannot be replaced in the detection of the bony lesions but they do not allow us to evaluate their development. We carried out some thermographic exams in 10 patients affected by

Paget's disease (6 in a polyosteotic form and 4 in a monosteotic form) with ages between 53 and 78, who underwent a calcitonine therapy (Calcitar), dosage 1 unit M.R.C./kg, twice every day, with cycles lasting one month, at intervals of one month. The laboratory tests did not show any sensible variation, except for the alkaline phosphatase whose value always came down during the treatment. In the same way, the thermographic pattern appeared modified with local reduced hyperthermia in all the patients tested (Fig. 1). Yet, not all the localizations showed the same degree of modification, and this is probably in relation to the higher vascular component with respect to that of the metabolic component in the pagetic localizations in a quiescent phase. Those latter localizations, in fact, are scarcely modified by the calcitonine therapy that, as is known, operates mainly on the metabolic component. This could lead to an erroneous interpretation of the efficacy of the therapy as well as that of the evaluation of the disease. Furthermore, some erroneous opinions can be caused by the technical difficulties of examining pagetic localizations in the pelvis where the thermographic pattern appears to be of doubtful interpretation. In conclusion, we can assert the usefulness of the thermographic test in Paget's disease. Though, thermography cannot lead to a differential diagnostic evaluation, it represents a useful help in evaluating the development of the Paget's disease, either during the remission period or during the treatment.

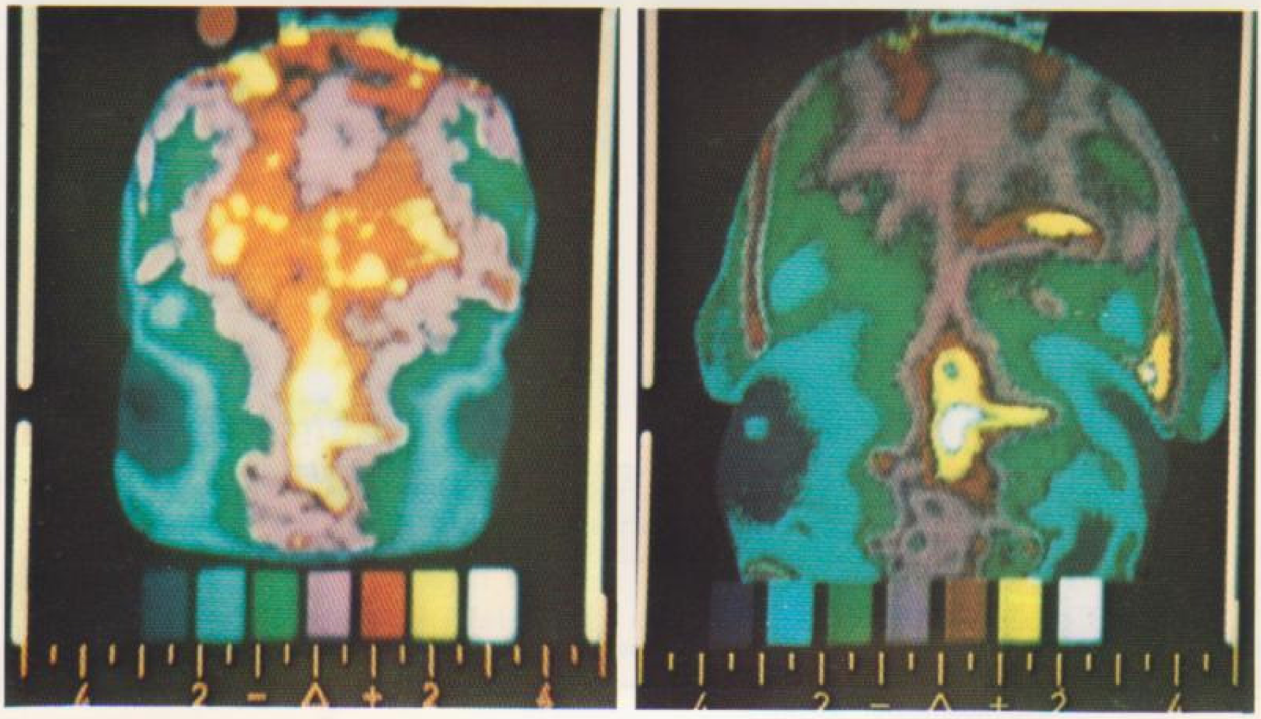
A  B

Fig. 1. A) Remarkable hyperthermia in the inferior angle of the right scapular and in the thoracolumbar junction visible on the right side at the level of the lower thoracic vertebrae. B) Thermographic control carried out at 5 months from the 1st test, after 3 cycles with Calcitonine therapy.

B. Talia, A. Landi (Modena, Italy)

Intra-operative thermography in micro-surgery: physiopathologic study of the carpal tunnel syndrome

The Authors report the results of intra-operative thermographic research in studies of the physiopathology of compressive syndromes of peripheral nerves. The study was carried out taking as a model the compression lesions of the median nerve of the wrist which can be included within the carpal tunnel syndrome. The aim was to check the validity of pathogenetic theses (both compressive and ischemic) which were expressed in the past and, particularly, to point out the eventual rôle of the vascular factor in this syndrome.

The investigation was carried out by means of an « AGA Thermovision 680 », with a 15°×15° lens and an extension ring to get the maximum magnification; this permitted exploration of an area of 4.6×4.6 cm. The thermographic investigations were carried out, at an average temperature of 21°C., at standard intervals of 10, 20 and 30 minutes after opening the tunnel and isolating the median nerve emerging superficially from the forearm up to the ramifications to the palm of the hand, and after removing the tourniquet when the haemostasis is completed.

The investigation was carried out on 7 patients where the carpal tunnel syndrome had been diagnosed both on a clinical and a physiologic basis, and 2 patients who underwent operation for Dupuytren disease. In these two patients, used as a reference, the results of the thermographic investigation were in accord with the report of the operative anatomic findings and pointed out a homogeneous thermal distribution all along the median nerve between the emerging of the palmar cutaneous branch to the forearm and the terminal branchings to the palm.

In the 7 cases of carpal tunnel syndrome, a segment of median nerve was seen to be constantly and significantly hypothermic (1°C) in comparison with the proximal and distal segments. In some cases it was also possible to see a fairly hyperthermic proximal or distal segment. The hypothermic segment coincided with the stenosis and thickening of the median nerve, whereas the hyperthermic segment, proximal or distal to the stenosis, was always related to the local condition of the circulation.

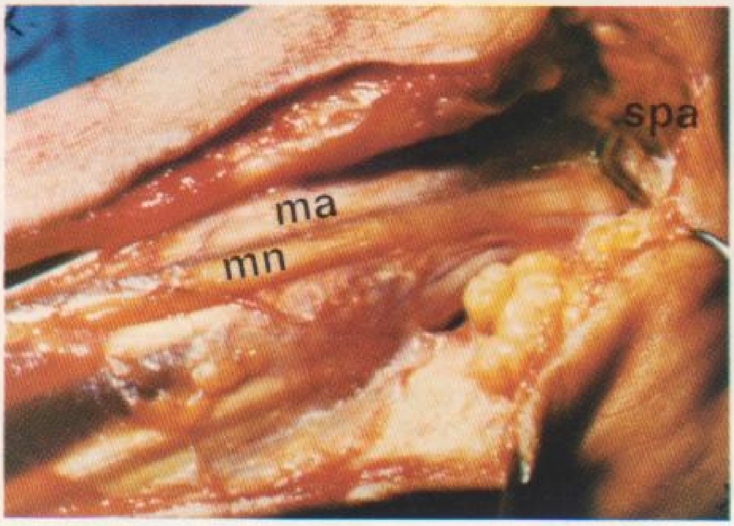


Fig. 1.

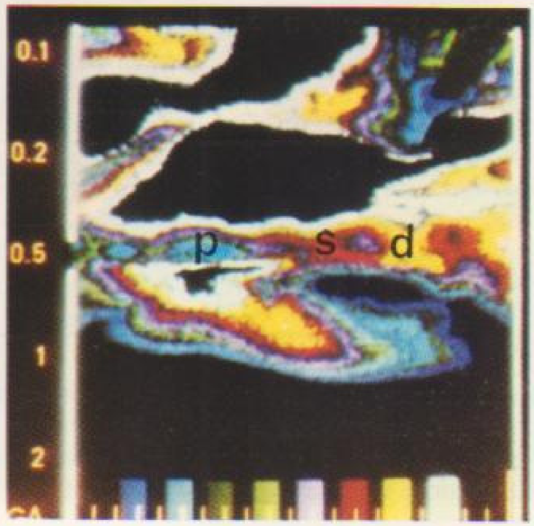


Fig. 2.

Fig. 1. V. A., 51 years old. Patient with carpal tunnel syndrome. Operative view after opening the tunnel; the median nerve (m.n.), the median artery (m.a.) and the anastomosis with the superficial palmar arch (s.p.a.) are clearly evident. Vascularization of the second type.

Fig. 2. Corresponding thermogram carried out by means of a 15°×15° lens and extension ring. The stenotic segment of median nerve (s) is hypothermic; the proxime segment of median nerve (b) is also hypothermic on account of the median artery compression; the distal segment of median nerve is hyperthermic (d) on account of blood supply from the superficial palmar arch.

There are three main types of blood supply of the median nerve: *a*) radial artery, ulnar artery and superficial palmar arch form an anastomic network within the tunnel: 70%; *b*) both median artery and superficial palmar arch are responsable for the vascularization of the nerve of the carpal tunnel: 20% (Fig. 1); *c*) only the median artery running along the nerve is responsable for its vascularization: 10%.

In conclusion the intra-operative thermographic data indicate the important rôle of the ischemic factor in the carpal tunnel syndrome. Also the thermographic information is very useful because it enables us to spot the surgical treatment within reasonable limits of inner or outer neurolisis; extremely useful to avoid adding surgical damage to the anatomic one.

Peripheral vascular diseases

G. Pompei, M. S. Saviano, B. Talia, F. Romani, G. Tuscano (Modena, Italy)

Study of venous pathology by means of telethermography

The introduction of new instrumental methods and procedures has widely contributed to the substantial clinical development of phlebology, with positive repercussions on diagnostics and hence on the therapy of the main venous diseases such as varices, thrombosis and chronic venous insufficiency. We have examined and evaluated the contribution of thermography (AGA 680) in venous pathology. The first field of application concerns perforating veins, presenting well-known limits to clinical exploration (digital research or use of multiple tourniquets, etc.) and the need for an exact location in order to carry out a correct surgical or sclerosing treatment. We used the technique of Patil and Lloyd Williams on 20 patients first examined by phlebography and then checked by the surgical intervention of subfascial ligature of the perforating veins. The surgical checking showed that the reliability of thermography was by far higher than that of clinical exploration, comparable to the phlebographic one (Tab. I).

Tab. I. **Comparison amongst the different methods of investigation.**

Methods	*Marked sites*	*Confirmed diagnosis*	*Diagnostic accuracy*
Clinical examination	41	32	51.6%
Thermography	59	51	82.2%
Phlebography	54	49	79.0%

Column one refers to the number of suspected perforating veins marked on the leg before surgery. Column two refers to the perforating veins found during the operation and that had previously been marked. The total perforating veins found during surgery was 62, as each method detected either the same sites of further ones. The diagnostic accuracy should be considered as the percentage of perforating veins detected by each single method in the 62 found during surgery. When compared to phlebography, thermography has the advantage of being noninvasive, absolutely free from any risk and well tolerated by the

Tab. II. **Comparison between Thermography and I^{125} Labelled Fibrinogen in the early diagnosis of acute venous thrombosis.**

Methods	*Positive*	*Negative*	*No. of cases*
I^{125} Labelled Fibrinogen	16 32.6%	33 67.4%	49
Thermography	10 20.4%	39 79.6%	49

Tab. III. **Thermographic accuracy and locations of the A.V.T.**

Location		*No. cases*	*Thermography*	
			Positive	*Negative*
Leg. Trunk		8	6	2
Femoro-politeal		9	9	—
Ileo-femoral:	without coll. circulation	4	3	1
	with coll. circulation	16	16	—

patient. It can be quickly executed by the common thermographs available in commerce, without any particular device, it gives good results and, furthermore, affords the advantage of a reproducible documentation, though being mainly a « visual » and « instantaneous » method of examination. Its use should be compulsory in the cases of recurrent varices and chronic venous insufficiency. The second field of thermographic application is the study of acute venous thrombosis. We analyzed the problem of prophylaxis of acute venous thrombosis (A.V.T.). This study was related to 49 patients, all subjected to operations of general surgery, comparable as to trauma and duration (over one hour). To this purpose we have checked the patients by the I^{125} labelled fibrinogen, whose diagnostic accuracy, in our experience, reaches 95/96%. (Tab. II).

Though diagnostic accuracy of Thermography in A.V.T. is inferior to that of fibrinogen, in a high percentage of the cases Thermography is able to detect A.V.T. even when no clinical evidence is yet present. In a second group of 39 patients clinically suspected of having deep acute venous thrombosis, all checked by phlebography, the thermographic picture generally consisted in a widespread increase in temperature all over the concerned area and in a considerable portion of the surrounding areas. Sometimes it has been possible to see the evidence of a superficial thrombo-phlebitis (heat increase all along the venous channels). According to the prevailing location, we had different results (Tab. III).

The results of thermography and phlebography did not correspond in only three cases: two cases of thrombosis in the posterior tibial veins and one case with ileofemoral thrombosis with large collateral circulation. Thermography can therefore be considered a simple and noninvasive method of diagnosis of A.V.T. which can be used instead of phlebography especially in the presence of a clinical correlation.

P. Rocco, M. Gangemi, G. Cennamo (Naples, Italy)

Thermography in cerebral vascular pathology

In recent years some authors have conducted thermographic research on patients of ophthalmological and neurological interest, giving precise indication for complementary diagnostic instrumental examinations in particular in the vascular pathology of the ophthalmic artery, in the mono and bilateral exophthalmias and in cerebral tumours. Our field of research is directed in particular towards patients affected by cerebral vascular pathology of different degrees where we have often associated thermographic research with carotid angiography. We have used an AGA Thermovision instrument (model 680 medical). Every patient was prepared for the examination by keeping him stationary for approximately 15 minutes in a room at constant temperature of 22-23°C and then before a ventilation for about 10 minutes. Each thermographic picture was executed with patient's eyes closed in order to make evident any variations in the eyelid. 40 patients were subjected to facial thermography; of these 10 presented an occlusion or insufficiency at the level of the internal carotid above or below the ophthalmic artery, 30 presented instead cerebral circulatory insufficiency (group D) (Tab. I). The first 10 patients, subjected to carotid angiography, are classified in the groups A), B), and C), the other 30 form group D).

Group A): Six patients who presented an occlusion of the internal carotid above the ophthalmic artery. Group B): Two patients who presented a narrowing of the internal carotid below the ophthalmic artery. Group C): Two patients who presented an occlusion of the internal carotid after the ophthalmic artery. In all patients of group A), on the basis of thermographic signs which are by now classical in thermography of subjects with steno-insufficiency of the internal carotid we have always observed the presence of hypothermia of the upper internal angle of the homo-lateral orbit, in 3 cases on 6, moreover, we observed a frontal upper orbital homolateral hypothermia, and in 2 of these last 3 cases we also observed a low collateral circle at the level of the external carotid in carotidography (Fig. 1). In the remaining 3 patients of group A) there was observed in thermography a hypothermia of the homolateral temporal and in only one of these a total nasal hypothermia. These 3 patients presented in carotidography a notable compensatory circle by way of the external carotid. The 2 patients of group B) presented a hypothermia of the upper internal angle of the homo-lateral orbit, a hypothermia of the homo-lateral eyelid and a frontal hypothermia of the upper homo-lateral orbit. The 2 patients of group C) both presented a slight hypothermia of about 1°C, or a little less, at the level of the upper internal angle of the homo-lateral orbit. In one of these cases there was also found a slight hypothermia of the frontal upper orbitary homolateral with equal thermal gradients. Both subjects, on the contrary, presented a clear nasal and frontal hypothermia. The 30 patients of

Tab. I.

	40 cases	*Hypothermia of the upper internal orbitary angle*	*Hypothermia of the same side of the eyelid*	*Frontal hypothermia of the same side of the upper orbitary*	*Bilateral frontal hypothermia*	*Nasal hyperthermia total and partial*	*Temporal homolateral hyperthermia*	*Frontal hyperthermia*
Occlusion of internal carotid artery above the ophthalmic artery	6	6	2	3	0	1	3	3
Stenosis of internal carotid artery below the ophthalmic artery	2	2	2	2	0	0	0	0
Occlusion of internal carotid artery after ophthalmic artery	2	2	0	1	0	2	0	2
Cerebrovascular insufficiency	30	4	4	—	19	6	—	8

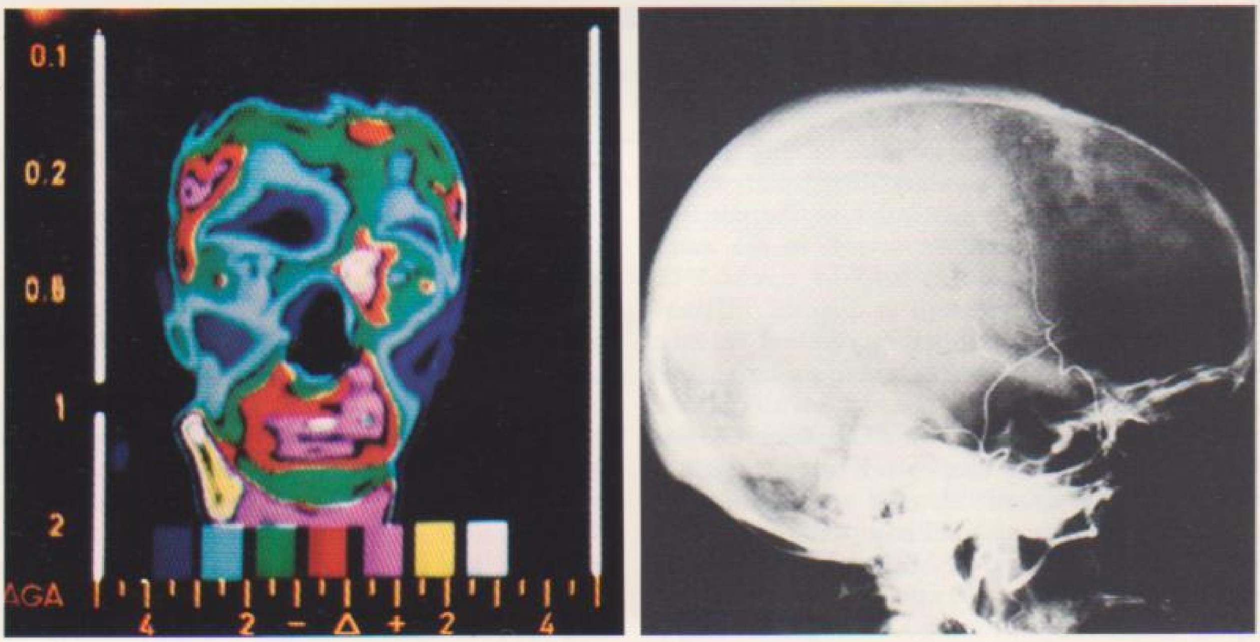


Fig. 1. Man 56 years: occlusion of the right internal carotid artery, before the origin of the ophtalmic artery with low compensatory circle at the level of the external carotid artery. Hypothermia of the upper internal angle of the right orbit with a frontal upper orbital omolateral hypothermia.

group D) presented clinically a cerebral circulatory insufficiency of ocular and neurological interest. Only 5 of these patients were subjected to carotidography (Fig. 2). The most significant signs were represented by a bilateral frontal hypothermia encountered in 19 cases and by a frontal hypothermie encountered in 8 cases. Of these last only 6 also presented a nasal hypothermia. From our experience, it seems evident that only 3 cases of group A) (subjects with occlusion at the level of the internal carotid of the mounts of the ophthalmic artery with little compensatory circle at the level of the external carotid) and both cases of group B) presented a complex of thermographic signs which led to a precise diagnosis, or at least led to the execution of particular neuro-radiological investigation. We retain that thermographic investigation is without any question useful for patients with cerebral circulatory insufficiency in view of the positive results encountered in group D) in 27 out 30 cases (19 with bilateral frontal hypothermie, and 8 cases with nasal hypothermia. Such research is particularly useful in those patients in which it is not advisable for various reasons to investigate by means of contrast medium. In these cases a positive thermographic result can orient us towards a diagnosis of vascular type of the disturbance. We retain, moreover, that such examinations are just as valid in periodic check-ups of subjects undergoing a therapy with drugs affecting the blood vessels.

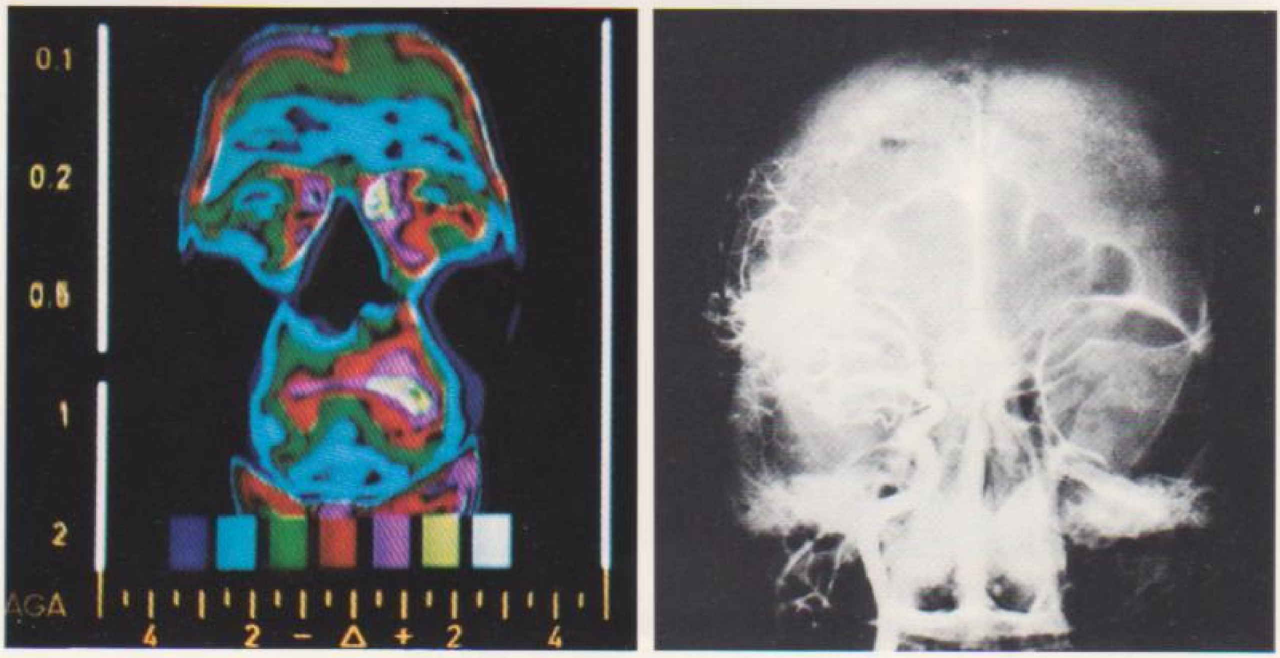


Fig. 2. Woman 48 years old with a cerebral circulatory insufficiency (bilateral frontal hypothermia).

G. Pastore, M. Carlesimo, G. Cina, E. Moneta (Rome, Italy)

Telethermography in the control of phlebitis in pregnancy

Thermographic investigation, in the dynamic and functional study of the superficial and deep venous system, is a method known for quite a long time (Gros et Al., 1966; Patil, 1970; Cooke, 1973). In pregnancy the venous pathology is an important risk element of the dreaded thromboembolic disease. This disease, in fact, often preceded by negligible signs of venous pathology, rarely appears during the 3rd trimester of pregnancy, but more frequently during the puerperium (0.24% of deliveries). In pregnancy, there is hematic hypercoagulation due to the physiological increase of fibrinogen, prothrombine, factors VII, VIII, X and perhaps IX and, by the second trimester, the venous flow to the lower limbs appears decreased and this is in relation to the increase in size of the pregnant uterus. The « high risk » pregnant women group was subdivided as follows: 1) patients with venous pathology in progress or present in their histories (alba dolens phlegmasias, superficial thrombophlebitis, suspect deep thrombophlebitis, thrombophlebitis or thromboembolic disease history, varices). 2) Predisposing factors (thrombocytosis splenectomy, multiparity, age, obesity, heart prostheses). The thermographic method, in addition to plethismography and echography, was preferably utilized for this group of patients since in pregnancy, because of the injuries that can involve the foetus, it is not advisable to employ angiography or I^{125} fibrinogen.

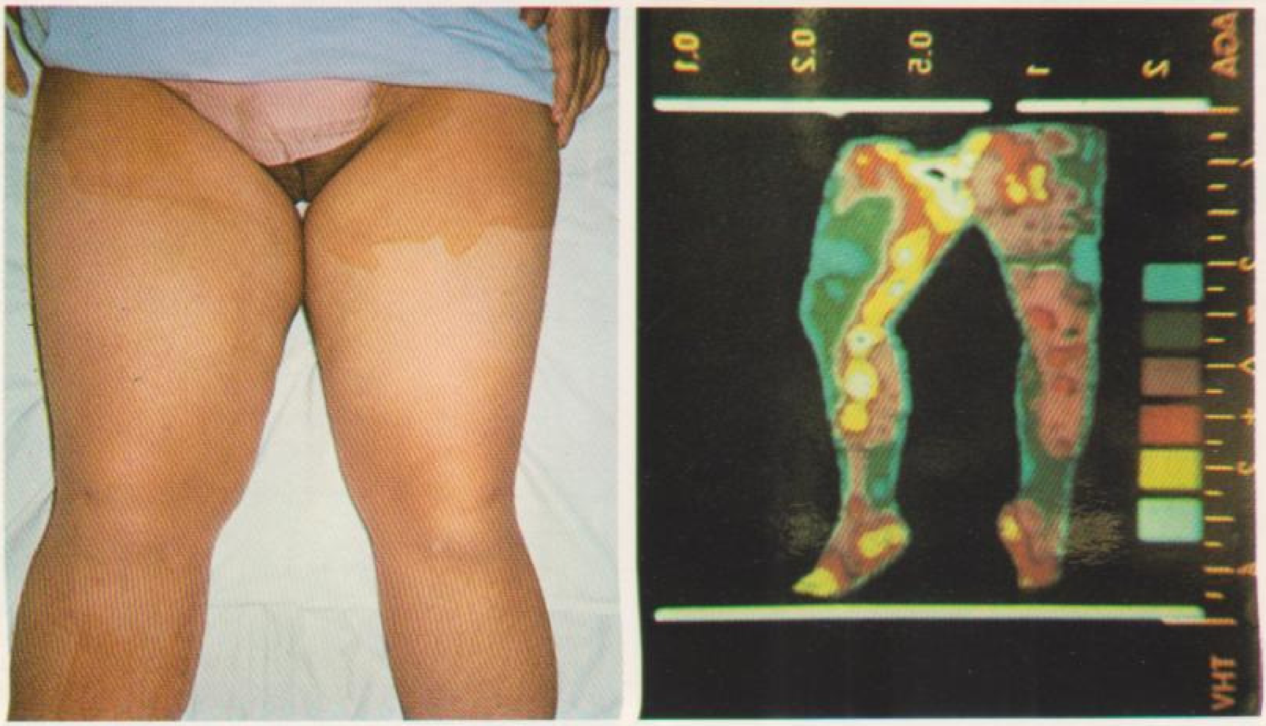
A  B

Fig. 1. A 21 year old patient, on the second day after caesarian section presenting oedema and enlargement of the right lower limb at the thigh level (A). Thermographically, hyperthermic cord along saphene vein (B).

Our study includes about 40 mostly aged obese pregnant women with varices and previous thrombophlebitis in the histories. These « high risk » patients were checked some during medical therapy, from the 6th to the 9th month of pregnancy. The thermographic method was extremely useful above all in the postsurgical control, as well as in the early diagnosis and topographic localization of phlebitis in pregnant patients who underwent thrombectomy owing to femoral-iliac phlebothrombosis. The case that we present is a 21 year old woman, in the third trimester of pregnancy, admitted into hospital for gestosis and pre-eclamptic syndrome. The patient, who underwent Caesarian section, showed, on the second day, oedema and increase of the diameter of the right lower limb at the thigh livel (Fig. 1). An anticoagulant and antiphlogistic therapy was carried out. The thermographic control showed, 15 days afterwards, an almost normal pattern which was confirmed also by the clinical course (Fig. 2). In conclusion the thermographic investigation of the venous pathology in pregnancy can: *a*) provide a quick diagnosis; *b*) show phlebitis sides; *c*) check the efficacy of the medical and/or surgical therapy; *d*) allow the monitoring of « high risk » patients.

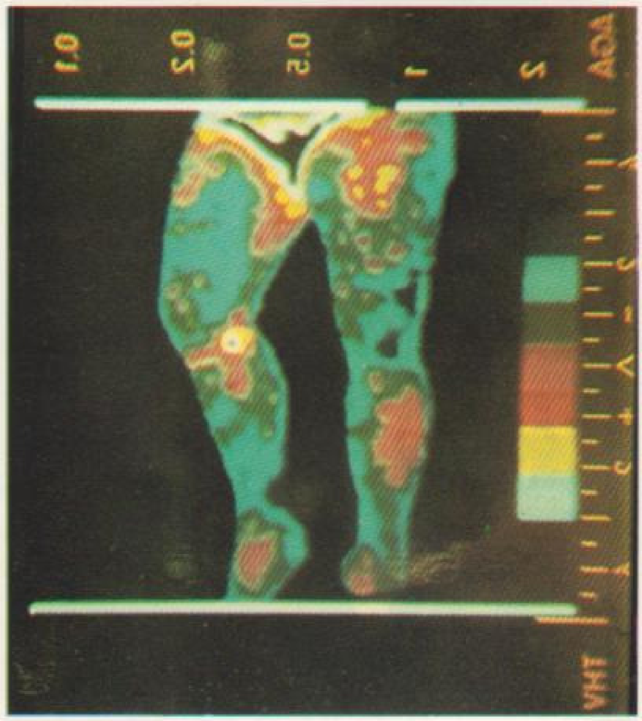


Fig. 2. An anticoagulant and anti-inflammatory therapy is started; at thermographic control, after 15 days, normalization of the pattern.

F. Romani, B. Talia, E. Belluzzi, G. Tuscano (Modena, Italy)

Results of telethermography in the sounding of chronic arteriopathies

The study of arterial diseases has gained, in recent years, a new technical instrument, the thermograph, which is particularly useful in evidencing thermic variations caused by pathological states which give rise to a diminished blood flow. Thermography is simple, non invasive and quickly repeatable. A group of 144 arteriopathic patients (ages ranging from 18 to 83) was subjected to thermography in order to evaluate its usefulness. Table I shows the distribution of the patients according to the location and the type of arteriopathia.

Tab. I. **Location and type of arteriopathies.**

Arteriosclerotic disease of the lower limbs	106
Diabetic arteriopathy	15
Arteriopathies of the upper limbs:	
— arteriosclerotic	4
— from repeated injuries	9
— vasoconstrictive forms	10
Total	144

Table II shows the surgical indications according to the clinical stage of patients with arterial occlusions below the renal level.

We have carried out 77 operations whose results have been controlled in the follow-up (Table III).

Tab. II. **Arteriopathies with occlusions below the renal level. Surgical indication according to the clinical stages.**

Clinical stages	*No. cases*	*Reconstructive operations*	*Amputations*
I	7	—	—
II	59	52%	—
III	13	90%	8%
IV	27	76%	20%

The best indication for thermography appears to be the possibility of a simple and systematic control of the operated patients, rather than the possibility of an early diagnosis. In arteriosclerosis, indeed, the thermographic picture depends on different factors (importance of the affected vessels, location and extension of the lesions) and at present thermography cannot give an exact picture of the side and intensity of the lesions. Furthermore, various factors affect the thermogram in the arterial disease patient and make interpretation quite difficult: the collateral circulation causes an increase in the superficial temperature which can hide an occlusion below. In the occlusive arteriopathies the spread of the disease leads to multiple areas of stenosis or occlusions and variable collateral circulation; the bilateral location then eliminates the possibility for an important comparison.

Other difficulties in the interpretation may be represented by the concomitant venous pathology due to ulcers, by the different thickness of the subcutaneous fat and, finally, by infections, as in diabetic patients. In these patients, we have appreciated the validity of thermography not as a screening method of the arteriopathies but as a method of therapeutic control or of indication for an appropriate medical therapy or surgical drainage. Finally it can help us to choose between a reconstructive treatment or an amputation.

Tab. III. **Surgical treatment.**

Aorto-bifemoral by-pass	10
Aorto-femoral by-pass	2
Iliac A.E.T.	10
Femoro-popliteal A.E.T.	9
Femoro-popliteal by-pass	8
Distal by-pass	3
Deep-plastic	6
Ganglionectomy { Thoracic 6; Lombar 13 }	19
Amputation	6
Various (cross-over)	4
Total	77

In the arteriopathies due to vasoconstrictive phenomena in the upper limbs, thermography can demonstrate which patients may obtail benefit from sympathectomy.

In the arteriosclerosis, thermography only confirms what is already evidenced by the clinical examination or other technical instruments. In the evaluation of the results of the surgical therapy it has given the most helpful data: A) the early or late success or failure of a reconstructive operation may be easily documented. The increase in tissue perfusion after a reconstructive operation may be useful as a prognostic index. B) Another possibility is that we can choose the exact level where it is necessary to amputate, by the visualization of the perfusion and hence of the vitality of the flaps, specially in distal amputations.

S. Lupieri (Trieste, Italy)

Thermography in arterio-venous fistula in the limbs (Case report)

A 9 years old boy suffered a lacerated wound, produced by a sickle, localized to the medial upper third of the right thigh. Sutures were applied and the patient was discharged after a few days. A year and a half later he started to complain about a moderate sense of heaviness, which increased under exertion, in the lower part of the right limb, and an increase in the size and lenght of the whole limb. Along the upper third of the right thigh, over the course of the superficial femoral, a throb was noted, which on ausculta-tion revealed a rough continuous murmur, with a certain amount of sistolic reinforcement. These are all signs that point to the existence of a post-traumatic arterio-venous fistula. An arterio-graphic examination showed a saclike neoforma-tion on the upper third of the superficial femoral and a precocious and evident return of the venous blood, signs of an important deviation of the arterial blood stream into the venous drainage of the femoral. At this point our investigative diag-nosis might have been considered established, there being no doubt about the existence of an arterio-venous post-traumatic fistula. There might only be some doubts about the exact location of the shunt as the arteriography offered only the possibility of guessing its location in connection with the saclike dilatation. There was no evidence however of arterial blood seeping into the venous blood stream. A thermography was done in the hope that it might furnish us the element which was not shown entirely by traditional investigations. In fact the thermographic examination fulfilled our expectations, giving us further evidence showing with greater accuracy the localization of the shunt at the level of the upper third of the superficial femoral. The photograph actually showed a right lower limb with an area of thermic gradients along the femoral in the upper median two thirds of the thigh, with a zone of particular heat which seems to correspond to the site of the fistula. Further-more it showed the presence of another small area with a thermal gradient of +3 and maximum heat production at the central third of the leg. This leads us to presume an excessive blood supply to the superficial system in view of the lack of communicating vessels, as noted already in a previous phlebography. On the basis of these diagnostic elements, an operation was performed on the patient (Prof. Pietri, 14.7.75). The post-operative arteriography shows the perfect canali-zation of the artery and the absence of residual fistulous passages. The post-operative thermogra-phy also showed a return to normal along the lenght of the limb which had been operated.

Summing up, it is possible to affirm that thermo-graphy does not represent a preferential method of examination in cases as described above; nor can it considered indispensable. However it may be, in some particular cases, a valuable aid for a total evaluation of the size of the shunt and, above all, a valid contribution for locating the exact site of the lesion, which often forms a deci-sive element for the surgeon when undertaking a corrective operation.

Remote control with thermography

C. de Renzis, G. P. Ausili Cefaro, A. Fusco (Rome, Italy)

Problems of telethermographic monitoring

Recent progress in THV with special reference to the measures of absolute temperature, has made necessary a greater accuracy in the tem-perature measurement providing, on the one hand, a better clinical utilization of the thermographic test, on the other, an easier possibility of repeating the test later. The thermograph behaves like a clinical thermometer, even if it is actually much more sophisticated and sensitive. It is interesting to analyze the procedure of taking periodic con-trol exams of the thermographic picture in order to show variations of vascularization or increases in cellular metabolism (neoplasias). Amalric et al., have already showed that this periodic control could be helpful also for studying the irradiated breast, but it is necessary that the detecting device always be perfectly calibrated. We think it is extremely important to mantain and control both the local temperature and the temperature of the subject: in this way, there is no risk of referring the thermographic images to artifacts. In order to allow a thermographic determination as constant as possible, that is to say absolutely independent either of any variation in the local temperature or in the subject's temperature, we have provided our THV room with some ordinary devices: near the patient we put a thermovariable resistence probe which is connected to an electronic thermostat, having a maximum error of ± 1°C, wisely used only cold light illuminating devices and limited the access of people into the THV room. Because of the thermic losses, we took care that the room doors and windows were shut and, furthermore, screened with heavy curtains. The conditioner is activated one hour before the test begins, directing the air-flow in the direction op-

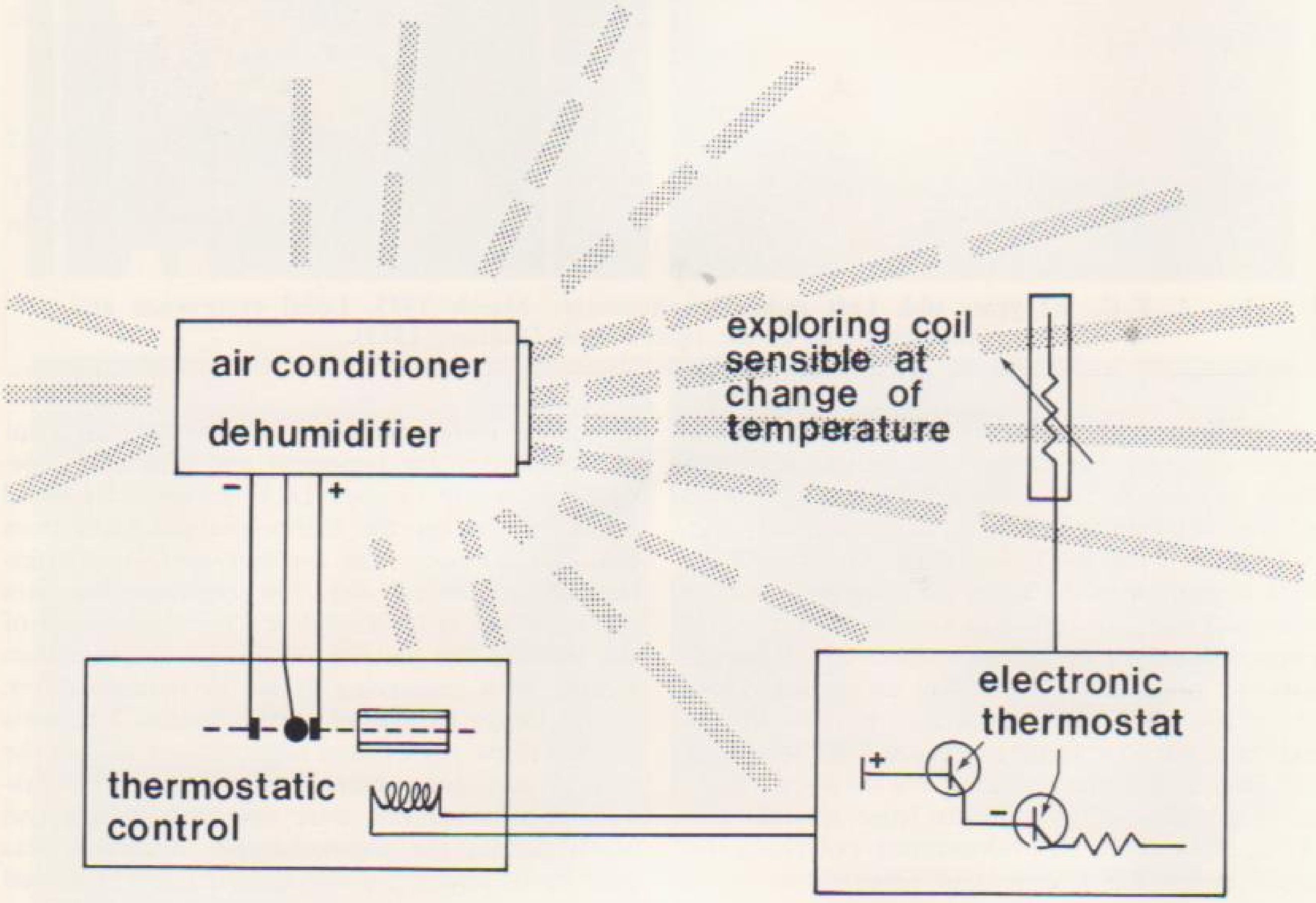


Fig. 1.

that can activitate a conditioner by means of an electro-mechanical control. The conditioner is able to supply 3400 standards refrigerating units with a capacity of removing humidity equivalent to 1.90 L/h (Fig. 1). In order to get the maximum output from this kind of equipment one must try to eliminate, as much as possible, the additional heat sources and avoid thermic losses. Thus we posite to the patient. The patient is always in the same physiologic conditions.

In conclusion, we can say that attention to such technical details has given us the possibility of comparing the THV patterns obtained over time and that the clinical results thus observed, in several fields investigated, are remarkable.

L. Trodella, P. Montemaggi, C. de Renzis, G. la Vecchia (Rome, Italy)

Thermography in the control of the skin metastases by breast cancer during chemotherapy

Skin metastases at the site of previous mastectomy and secondary carcinoma mastites of the controlateral breast are of relatively frequent observation in oncological clinical practice. Today's therapeutical trends, if one excludes surgical extirpation, lean towards radiant or chemoterapic treatment or the two systems combined together. Hence, the importance of the periodic employ-

Fig. 1. F. C., 62 years old. Left radical mastectomy: March 1973. Local recurrence and mastoschirrus of the right breast. (January 1975).

ment of the telethermographic investigation in these subjects. For about two years, we have been following, by thermography, the evolution of the skin metastases during chemotherapy, and, already in April 1975, in Milan, at the meeting held in the Sormani Palace, we were able to communicate our first data. The results obtained were encouraging. We periodically observed 28 mastectomized patients for mammary carcinoma. 19 of them presented skin metastases at the site of previous surgical intervention, and 9, secondary carcinoma mastites of the controlateral mammary gland. All the subjects were treated with ADB, 5FU, CTX and testosterone polychemotherapic cycles for 8 days and repeated every 30 days. The thermographic control was carried out before starting the treatment and afterwards, periodically, every 15 days. In 17 patients, we could observe a fall of the therm gradient right from the 10th day up to the thermographic negativization around the 19th day. The thermographic data corresponded to the complete clinical remission of the lesions. The patients of this group were then treated with preserving cycles at reduced doses, with a longer interval of administration. 7 patients did not show any evident improvement and, at the clinical and thermographic investigation, no substantial modifications were observed. At the end of 3rd cycle, the chemotherapic treatment was interrupted and this group of patients was treated

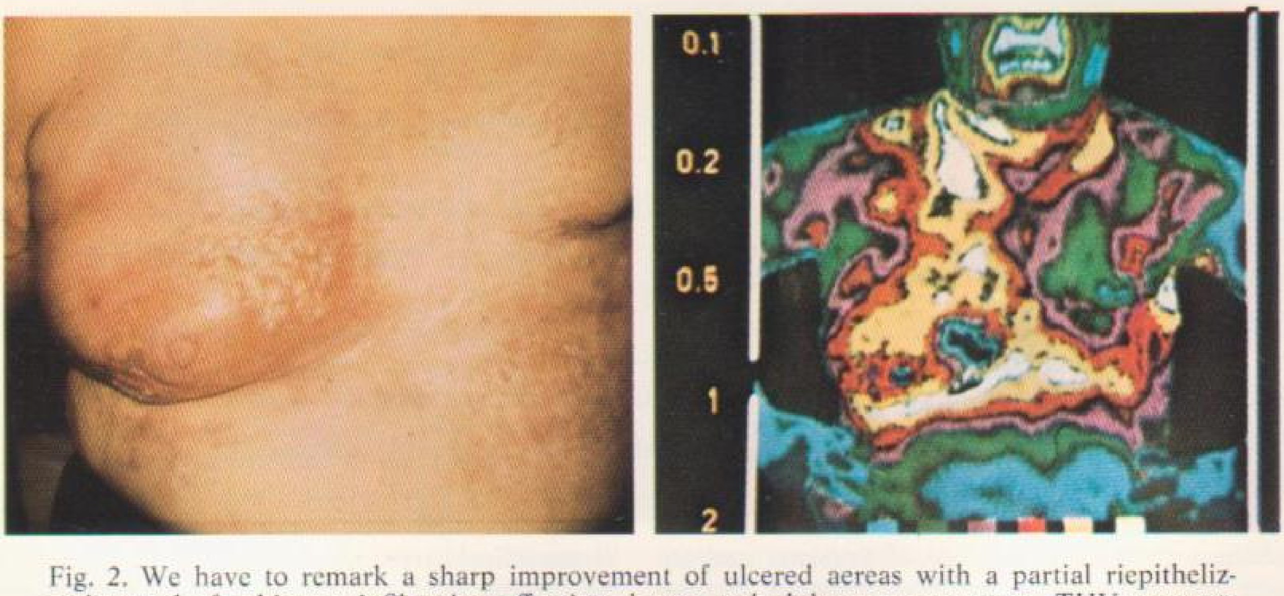


Fig. 2. We have to remark a sharp improvement of ulcered aereas with a partial riepithelization and of schirrous infiltration affecting thorax and abdomen upper part. THV supports clinical picture; because of the steadly positive pattern, the A.A. rept up chemotherapy.

with radiant therapy with good clinical results. Thermographically, we had, in these subjects, a sudden and remarkable thermic rise because of the attinic dermatitis. The 3rd group (4 patients), after an initial fall in the thermal gradient, at 60th days from the beginning of the chemotherapy, showed a clear resumption of the disease, evident both at the clinical and thermographic investigation. For these nonresponsive patients, we changed the therapeutical scheme by administrating a new pharmacological combination (CMF), with a good and clear response. In conclusion, the role of telethermography in the monitoring of skin metastases from mammary carcinoma during radiant or antiblastic chemotherapy, showed itself to be useful and essential not only to ascertain the evolution of the disease but overall to plan and formulate the therapy.

L. Fogher (Trieste, Italy)

Thermography of autoplastic transplants and plastic reconstruction after radiation therapy

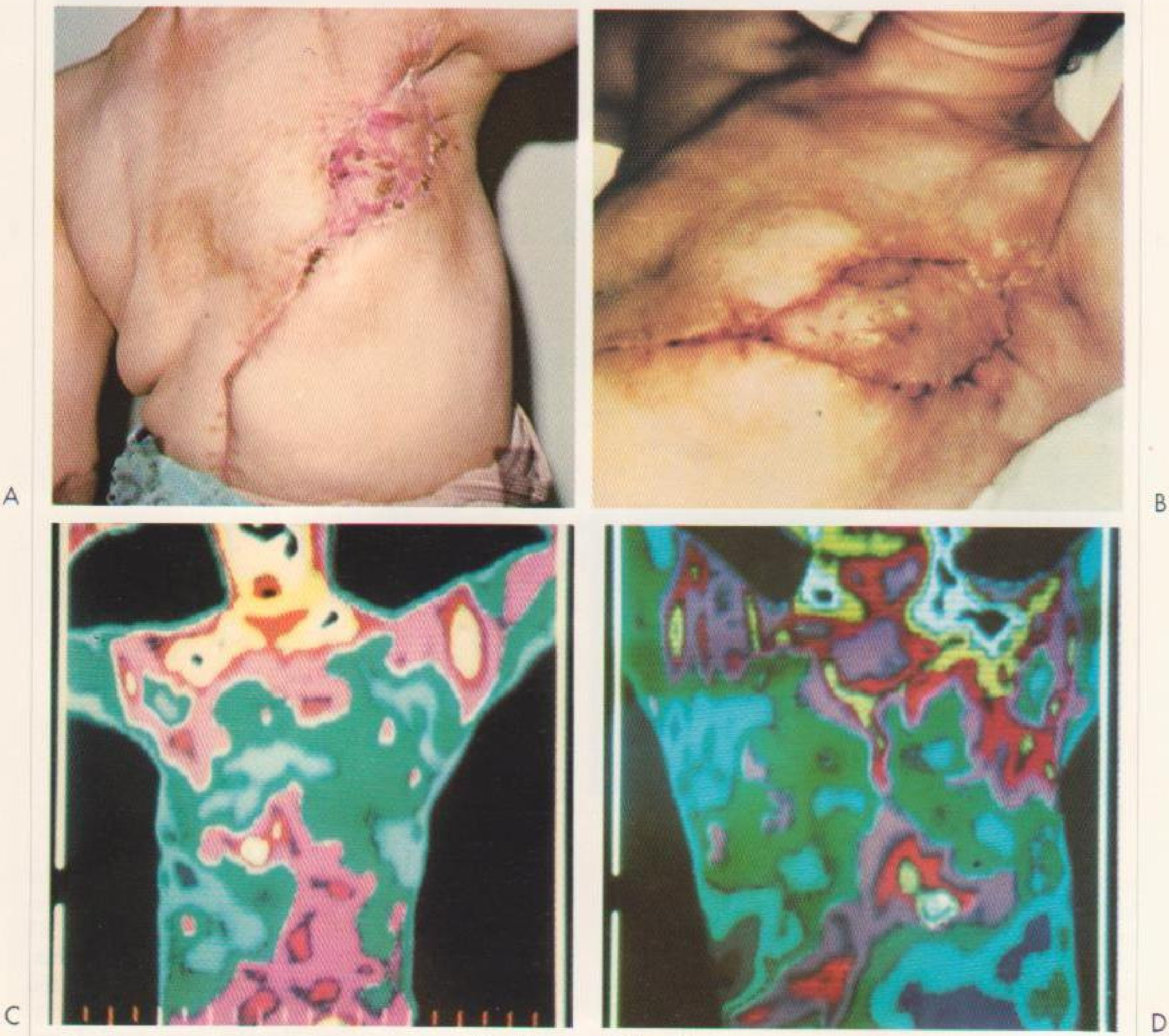


Fig. 1 A-B-C-D. Case 1.

Two cases of plastic reconstructive surgery for necrotic or ulcerated lesions after radiation therapy in cancer of the vulva and in cancer of the breast were examined thermographically.

Case I. A 54-years-old female underwent left mastectomy, with excision of the axillary lymphatics, hysterectomy with bilateral adnexectomy and began cycles of high energy radiation therapy in 1964. In 1965 she underwent right mastectomy and further radiation therapy. In january 1975, she was readmitted with vast ulcerated and necrotic skin areas (Fig. 1 A). Plastic reconstruction was done in september, 1975 (Fig. 1 B), and the autoplastic transplant was examined thermographically. These thermograms showed that the transplant had taken well and had 2 hyperthermic areas that required local anti-inflammatory therapy (Fig. 1 C). Later thermograms showed further good take of the transplant (Fig. 1 D).

A

B

C

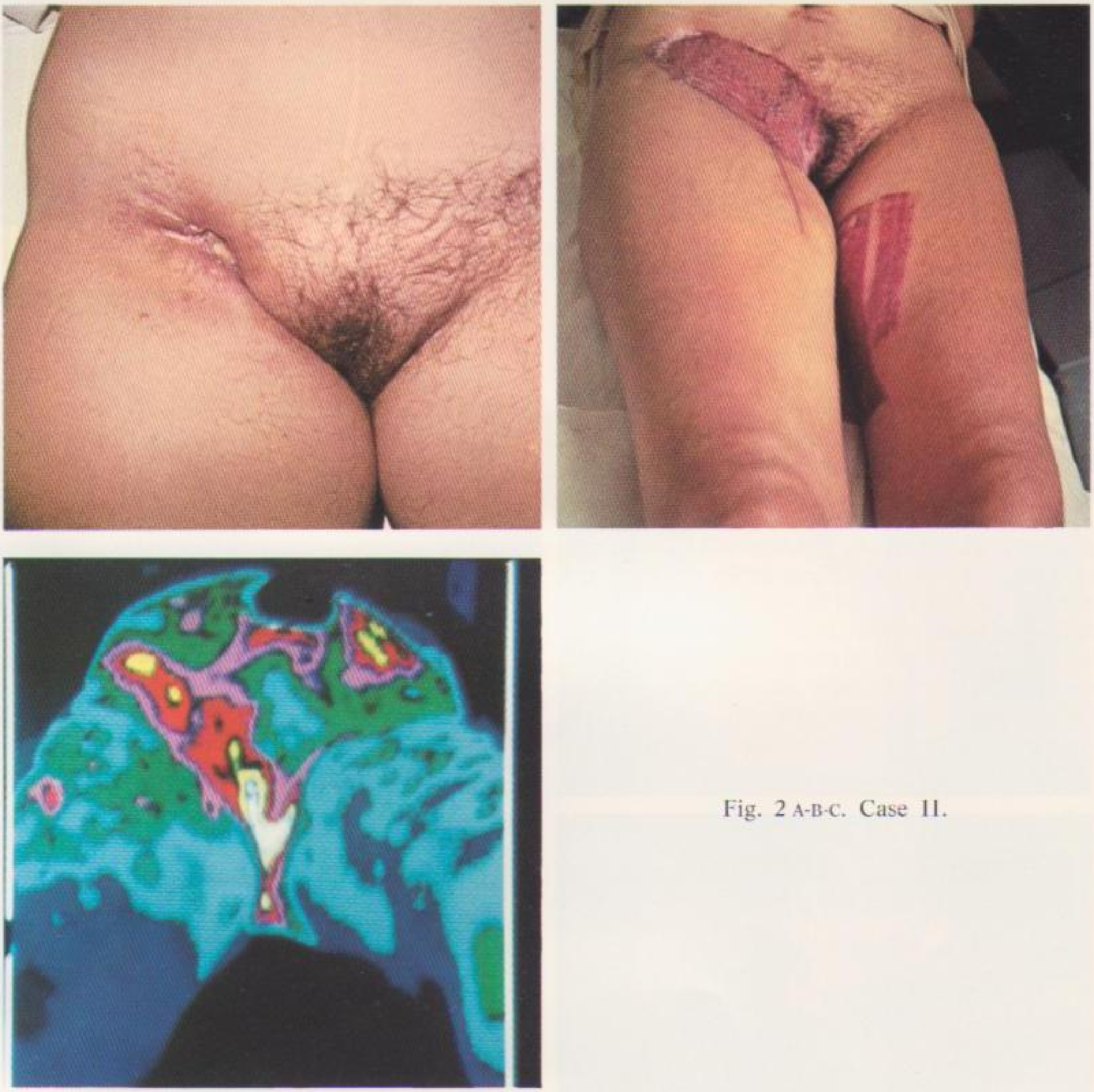


Fig. 2 A-B-C. Case II.

Case II. A 44-years-old female with epitelioma of the vulva received 8.10 millicurie by implantation of radium needles in 1962. In june 1963 she received 5.40 millicurie as therapy of a relapse. In january 1965, an other relapse was treated surgically and with long-distance betatron therapy. Short-distance betatron therapy was carried out in october 1965. 10 years later she was admitted with necrotic ulcers in the right vulvo-inguinal region. In may 1976, a partial zonal plastic reconstruction was done. Thermograms after this surgery showed hyperthermic areas (3 and 4-5°C) within this zone (Fig. 2). In conclusion it is thus evident that thermography is very useful in monitoring the biologic activity of autoplastic transplants and plastic reconstruction after radiation therapy which has led to radionecrosis.

OBITUARY

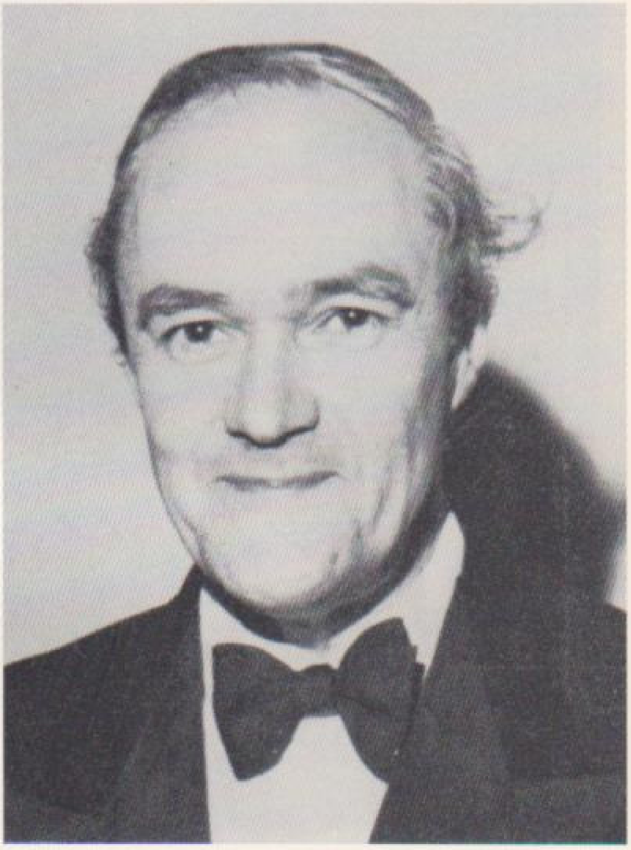
Raymond Oliver

M. A. (Oxon), D. Sc. F. Inst. P., F. Inst. Biol., F.I.E.E.

Raymond Oliver died on March 5th 1976 aged 55. He was professor of medical physics at the Postgraduate Medical School London for the last five years of his life. From 1945, he had worked in medical physics first in the London Hospital and later as principal physicist and Radiation Protection Officer at the Radiotherapy Unit at Oxford.

His published work (over 150 papers) covered many different aspects of medical physics and radiobiology. Thermography was one of his interests which developed while he was at Oxford. His publications with Watmough on the factors affecting infra red thermography of curved surfaces are often quoted. Another publication showed his interest in the performance and standardisation of thermographic equipment. When he left Oxord for his chair in Medical Phyics his interest in thermography continued although he was unable to continue his studies in this field. He became an active member of the European Thermographic Association and English secretary of the Teaching Comission on Thermography. He continued this office even after knowing that he was suffering from a cerebal tumor. He continued his work and travelled to meetings for as long as possible. His quiet, pleasant manner and efficient expertise marks him as a man who will be greatly missed by his many colleagues.

(E. F. J. Ring)



RAYMOND OLIVER
1921 - 1976

THERMOGRAPHY IN THE WORLD

▪ **BRATISLAVA (Czechoslovakia).** *4th Czech Radiology Congress.* During the 4th Czech Radiology Congress, held in Bratislava, from the 1st to the 3rd of September, 1976, many papers of thermographic interest were presented by authors from ever the country: *Thermography in angiology*, by Z. Chudacek (Plzen - Czechoslovakia); *Thermography, scintigraphy and radiography in the early diagnosis of bone neoplasias*, by C. De Renzis (Rome - Italy); *Improved cutaneous liquid crystals breast thermography*, by W. W. Logan (Rochester - USA); *Thermometric evaluation of contrast media effect and small vessels disease during angiography*, by K. Mathias; F. J. Roth; U. Goerttler; E. P. Strecker (Freiburg - West Germany); *Breast thermography in comparison with mammography and clinical data*, by G. Otto (Berlin - Germany); *Thermography, nuclear imaging and ultrasound in the localization of the placenta*, by G. Pastore (Rome - Italy); *Comparison of the value of mammography, nuclear imaging, thermography and ultrasound in the early diagnosis of breast lesions*, by E. Pluygers; M. Beauduin; G. Destailleur, M. Rombaut (Jolimont - Belgium); *Thermography with liquid crystals*, by P. Smoranc, O. Psenicka (Mradec Kralove - Czechoslovakia); *Comparison of the pattern obtained by liquid christals and by the thermovision camera*, by P. Smoranc, J. Svozoda, Z. Bakalar (Hradec Kralove - Czechoslovakia); *Thermography by means of liquid chrystals in scleroderma*, by H. Tauchmannova, O. Hazoc (Czechoslovakia); *Computerized thermography of osteoarticular disorders*, by E. F. J. Ring (Bath - United Kingdom).

*

▪ **CRETEIL (France).** A thermographic course on cholesteric thermography with liquid crystals (contact thermography) in breast diseases, was held on the 16th of November 1976 at the County Hospital of Creteil. The following subjects were treated: 1) *Thermic physiology* (C. J. Huber); 2) *Material and methods* (M. Gautherie); 3) *Thermic symptomatology* (C. J. Huber); 4) *Thermography in breast diseases* (J. Y. Pons).

*

▪ **VERONA (Italy).** 14th National Congress and 27th Symposium of the Italian Society of Surgery of the Hand was held in Verona from the 6th to 7th of December 1976.

During the congress many papers on thermography were presented: *Liquid crystal thermography of the hand* (U. Ambanelli); *Thermography of the hand: technique* (L. Acciarri); *Thermography in skin flaps* (L. Cugola); *Thermography in vascular lesions* (L. Cugola); *Vibrating tool disease* (L. Acciarri); *Thermography of traumatic lesions of nerve* (L. Cugola); *Intraoperative thermography in carpal tunnel syndrome* (P. Bedeschi); *Thermography in tendinous synovitis* (L. Cugola); *Thermographic follow up of calcitonin therapy in Suddeck disease and in osteoporosis* (L. Nogarin; *Thermography in carpal navicular osteomalacia* (A. Prinzivalli); *Prosthesis thermography* (L. Cugola); *Degenerative arthritis and thermography* (U. Ambanelli).

★

■ **STRASBOURG** (**France**). A post-graduate course of breast Thermography was held in Strasbourg from 9th to 11th of December 1976 at Radiology Department, Faculty of Medicine: organizing Ch. Gros. On the first day, the basics and the techniques of infrared and liquid crystal thermography were reviewed and their complementary examinations, clinical, radiological, and ultrasound, were treated. On the second day, there were demonstrations of new products and interesting slide lectures. On the third day, there was a round-table discussion.

★

■ **PIESTANY** (**Czechoslovakia**). The Ist Symposium on Thermography in CSSR will be held in Piestany on 19th-20th May 1977. Chairman of this meeting is Professor Lanyi, secretary Dr. Tauchmannova. Main topics of the Symposium: correlation of thermography with invasive methods in the diagnostic investigation of breast and bone tumours, the use of thermography in several fields of clinical medicine (rheumatology, urology, haematology, nephrology); thermography in experimental research.

★

■ **MARSEILLE** (**France**). The 6th International Seminar of the French Club of Clinical Thermography will be held in Marseille from the 23rd to the 26th of May, 1977 President of the Seminar will be J. M. Spitalier, secretary R. Amalric The Congress will be held in the Palm Beach Hotel (Promenade de la Plage). Official languages are English and French.

6 arguments will be treated: 1) *Thermographic prognosis in cancers*; 2) *Thermography in the world*; 3) *Thermography in thyroid diseases*; 4) *Thermography in breast diseases*; 5) *Thermography in vascular diseases*; 6) *Thermography in osteoarthropathies*.

There will be a technical exposition. Papers, presented at Seminar will be published. Many social programs and post-congress excursions are planned.

Registration fee: 500 french francs until the 30th of January 1977, 600 french francs after that date.

Registration and Information: Club Francaise de Telethermographie Clinique. BPN no. 179, F. 13275 Marseille Cedex 2 (France).

★

■ **BATH** (**England**). Meeting of the groups on Therminology and Teaching, on Industrial and Ecological Thermography, on Biothermometrology, of the Executive Committee and of the National Delegates of the European Thermographic Association.

In the former report of this meeting (Acta Thermographica, Vol. 1, No. 2, pg. 108) for a type setting error, the partecipation of Dr. J. R. Barker at the work of Biothermology groups was omitted.

The section concerned should read like this: « Dr. J. A. Clark (Nottingham) gave a practical account of the various factors affecting thermography with particular reference to animals, and to errors of measurement. Dr. J. R. Barker (Bath) gave an account of a mathematical model of the heat flow within a breast with a tumour, together with computed results for its behaviour under various conditions of skin cooling etc. ».

NEW BOOKS

■ **FUNDAMENTAL ASPECTS OF MEDICAL THERMOGRAPHY:** by W. M. Park, and B. L. Reece. Teaching booklet no. 3. Published by the British Institute of Radiology, London, 1976. The British Institute of Radiology, 32 Welbeck Street, London W1M.7PG.

Teaching booklet no. 3, « Fundamental aspects of medical thermology », written by W. M. Park and B. L. Reece, has been recently published by the British Institute of Radiology, and it is devoted to medical Thermography.

It is a very quick book and its main part deals with the physics of infrared radiations.

Moreover, clinical indications for thermography are well outlined.

Therefore we believe that all thermographers should be familiar with this booklet.

Contents of the book: 1 - *Introduction*; 2 - *Infrared radiation*: a) dependence on temperature, b) dependence on surface properties, c) curvature of the surface, d) dependence on environmental conditions; 3 - *Ifrared imaging*: a) detection, b) image scanning system, c) instrument performance and calibration; 4 - *Clinical applications*: a) information content of the thermogram, b) preparation measures, c) camera procedure, d) the normal, e) primary conditions of the skin, f) subdermal conditions, g) the extramities, h) the back, i) abdomen, l) malignant disease; 5 - *Ancknowledgements*; 6 - *Appendix 1*; 7 - *Bibliography*.