The thermographic hand

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SUMMARY. In the pathology of the hand, either directly or indirectly linked to vascular modifications, thermography can give information of great value both from a prognostic and diagnostic point of view. Thermographic data can complete and, at times, supplant data provided by clinical investigation and instruments hitherto in use.

In the field of primitive vascular lesions thermographic information has, above all, prognostic value in vibrating tools angiopathy. No less important is the effect of thermography in both nervous or vascular traumatic lesions and in osteo-articular lesions, which lead to clear circulatory modifications; and in this sector thermographic data has above all prognostic value. What is more it makes possible a correct valuation, at a distance, of the effectiveness of treatment both medical and surgical.

Key words; vascular lesions, nervous lesions, osteo-articular diseases, thermography.

INTRODUCTION

The hand is characterized, from the Morphological point of view, by an extended surface and a reduced thickness. This distinctive feature allows every change of heat production, at whatever depth it may be produced, to transtmit itself to the skin surface modifing the normal thermographic pattern of the hand.

THERMOGRAPHIC PATTERN OF THE NORMAL HAND

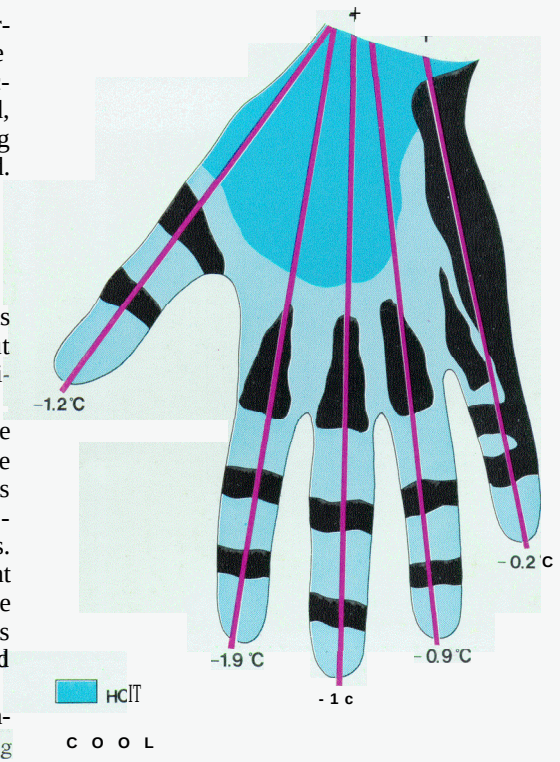
The normal hand has a non homogeneous thermographic pattern, that is variable, but nevertheless sufficiently regular to be classified [1 9] (Table I).

The dorsal carpal region is warmer on the radial side but cooler on the ulnar side. The metacarpal region is uniformly hot. Fingers are isotherms with cold areas at the metacarpo-phalangeal and inter-phalangeal joints.

There is a Longitudinal Thermal Gradient (LTG) between the heat of the carpus and the cooler temperature of the fingers with values ranging from 1.9 °C (to the 2nd finger) and 0.2 °C (to the 5th finger).

Another important parameter is the difference of temperature (Δ t) between corresponding

Tab. I. Normal hand. Map of thermographic distribution.



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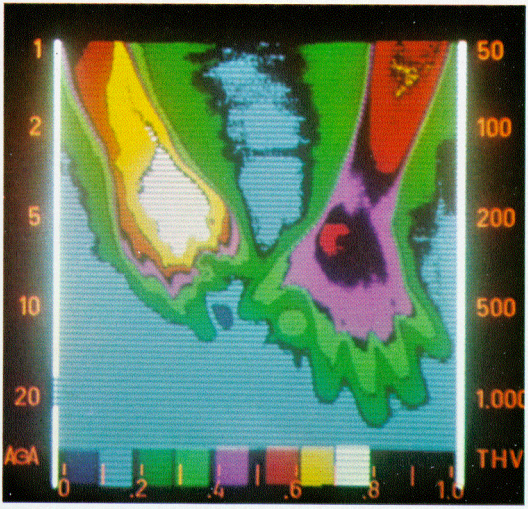

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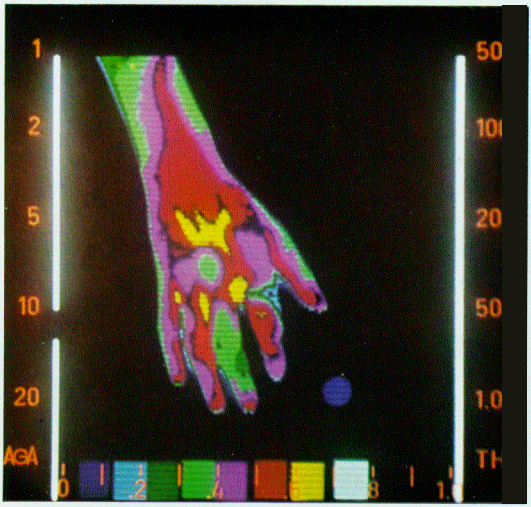

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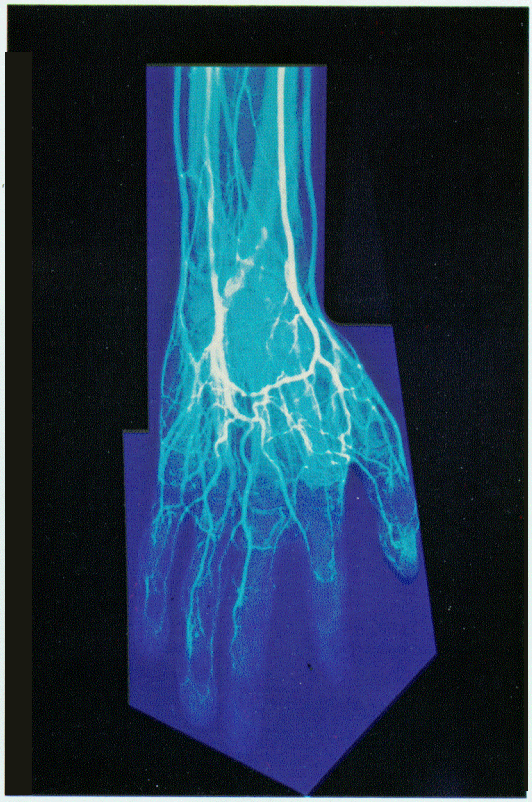

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Fig. 1 A-B-C-D-E Case 1. (A) Injury of the 2nd finger of the right hand with incurable section of the digital artery. (B) Thermographic pattern: 4 °C hypothermia. (C) Control after 3 days: thermal pattern is normalised. (D) Arteriography, collateral circulation below the amputation of the digital artery of the 2nd finger.

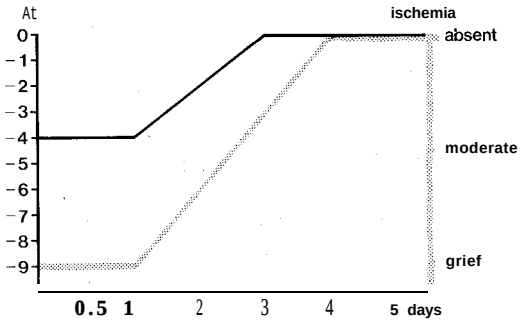

Fig. 1 (E) Graph of thermal (———) and clinical ▨ modification of this patient.

zones of the two hands; in the normal hand there is no difference.

PATHOLOGICAL THERMOGRAPHIC PATTERNS

The main causes of thermal distribution alterations at hand level are:

- vascular diseases;
- nervous diseases;
- osteo-articular diseases.

This paper however analyses only the thermal alterations directly or indirectly related to the vascular changes.

I VASCULAR LESIONS

Vascular lesions with bloodflow reduction are thermographically characterized by a hypothermia related to damage importance; among them traumatic lesions are very important, for they can cause serious infirmity.

A) ACUTE TRAUMATIC LESIONS OF THE VESSELS

These may be either contusions or vessel sections.

1. Vessel contusions

Here the clinical problem is the early recognition of a thrombosis which would require a surgical deobstruction in order to avoid the necrosis of ischemic district. Clinical signs of thrombosis appear relatively late; in thrombo-'sis of digital arteries they become clear 2 or 3 days after the obstruction has arisen; on the contrary, the thermographical pattern changes immediately. Without a sufficient collateral circulation there is a sudden thermic fall with a hypothermia greater even than 10 °C; so the thermographic data allows a timely surgical deobstruction.

2. Vessel section

Two situations are possible:

a) *Vessel section without any possibility of surgical treatment.*

In this case thermographic data are very important.

Indeed, in a section of a digital artery with thermal amputation and clinical ischemia, surgical amputation is unavoidable. On the other hand, when, with important clinical signs of ischemia, the thermographic pattern reveals a relatively moderate hypothermia (At = 2 - 4 °C), this means that there is a sufficient collateral circulation (Fig. l), and thus the surgeon may still hope to preserve the fingers.

In effect, without any other complication (eg. thrombosis of collateral circulation), the thermographic pattern will regularize within 2 or 3 days, confirming a favourable evolution. The clinical signs, slower in regularization, are less determinative than the thermographic signs.

b) *Surgically curable vascular sections.*

The reimpantation of fingers which have been cut off is a demonstrative example of this.

The role of 'thermography in this istance is the post-operative follow-up and the detection of possible complications [2], namely thrombosis or cicatricial stenosis.

After the reimplantation there is initially a rapid restoration of warmth to the fingers, then the thermal level increases more slowly. Within a few days,(about 5) the thermographic feature is practically normal (Fig. 2). Thermographic follow-up must be extended till the 20th day for it is in that period that complications may occur.

In the cases studied (3 reimplanted fingers) no complications occured in the post-operative period.

Thermical amputation of the reimplanted fingers, is the sign of a thrombosis or of a cicatricial stenosis, and makes necessary an immediate deobstructive surgical intervention.

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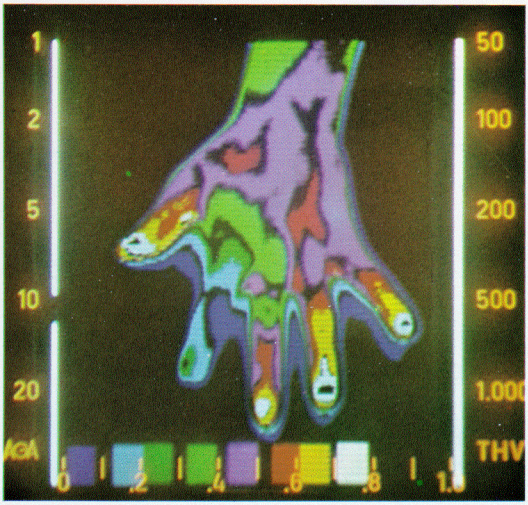

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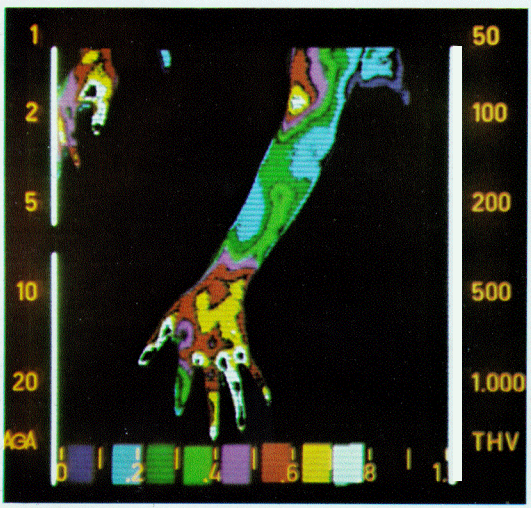

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Fig. 2 A-B-C-D-E *Case 2.* (A) Amputation of the last phalanges of the 2nd finger of the right hand. (B) Thermographic control 5 hours after the replant: hypothermia of 5 °C oF the 2nd finger. (C-D) After 5 days only a modest hypothermia was discernible (less than 2 "C): the clinical report of which showed normal development.

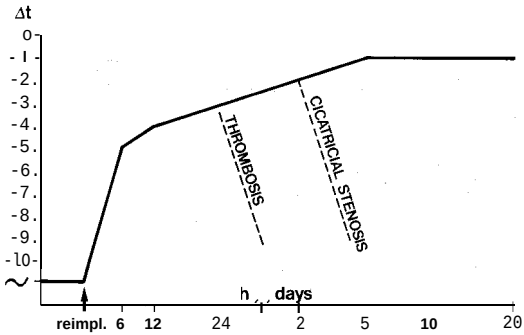


Fig. 2 (E) Graph of the thermal modifications after the replant.

B) MICROTRAUMATIC VESSEL LESIONS (Raynaud phenomenon from vibrating tools)

The clinical problem is to objectify the vascular lesions from repeated microtraumatisms. This is important also from a forensic point of view, because these lesions are an occupational disease.

Among the instrumental tests (oscillography, rheography, photopletysmography, thermometry) only photopletysmography is of any value, but it is necessary to complete it by a cooling test which is very painful for the patient. Angiography can demonstrate some very clear patterns, particularly in the advanced stages, but it is a very traumatic method and thus it should not be considered as a routine examination.

'Twenty five patients affected by Raynaud phenomenon were examined in our Institute. Thermography was abnormal in 84% of the cases at basal state (without cooling test); it showed a hypothermia of the metacarpi and of the fingers, with a constant growth of LTG. According to the modalities of work, the damage was unilateral (52.4%) or bilateral (47.6%).

In the bilateral lesions all the fingers were affected; in 64% of unilateral lesions hypothermia was localized.

The cold immersion test in angiopathies is characterized by a very much slower return to base-line values; the time required is 40 minutes or more. The cold immersion test increased positive results from 84% to 89.5% in the cases tested, and false negative results decreased by nearly 30%.

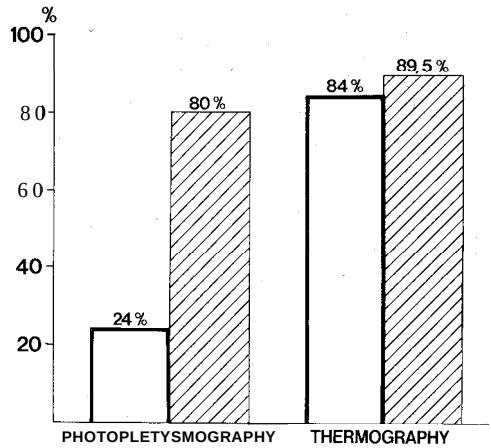
Table II makes a comparison between the data of photopletysmography and thermography in the cases studied. Photopletysmography provided a positive results in a basal state in only 24.% of the cases. After the cooling test the rate of positivity increased up to 80%.

Thermography provides for the basal state the same numerical findings as pletysmography after the dynamic test; and therefore the cooling test may be reserved for patients with negative thermography in the basal state.

II NERVOUS LESIONS

Important circulatory modification can be produced by indirect mechanisms acting on peripheral nervous systems [6]; particularly interesting are those produced by nervous le-

Tab. II. Vibrating tools angiopatby. Comparison between data photopletysmography and thermograpby under standard conditions ❑ and after cooling test ▨.



sions of the forearm, both traumatic and of non-traumatic compression (canalicular syndrome) .

A) **TRAUMATIC LESIONS**

In the traumatic lesions treated by nervous suture, the main clinical problem is the early identification of abnormal nervous regeneration. This allows a reduction of the, complications due to abnormal regeneration such as: skin distrophy or muscles atrophy.

1. Correct regeneration criteria

At this moment the criteria for a correct nervous regeneration are:

a) *Tine1 sign:* this is a subjective datum of nervous regeneration. It is a precocious sign, but it has no prognostic value.

b) *Moberg test:* this indicates the recovery of the sweating function and it is very reliable, but it is useful only in the later stages.

c) Electromyography: is very indicative of a correct regeneration and also provides a quantitative measure, however it also becomes positive only in an advanced phase. Negative results from these tests suggest pathological nervous regeneration, and the need for surgical intervention.

2. Normal nervous regeneration; thermographic patterns

In the nervous section of the forearm a thermographic pattern develops in a very characteristic manner, giving important indications of the regeneration.

Eight nervous lesions of the forearm, involving the medial and ulnar nerve, all treated by nervous suture were studied by thermography (a control every 10 days till the recovery or the stabilization of the lesion).

No differences were noticed in the evolution, in the case of either of the two nerves.

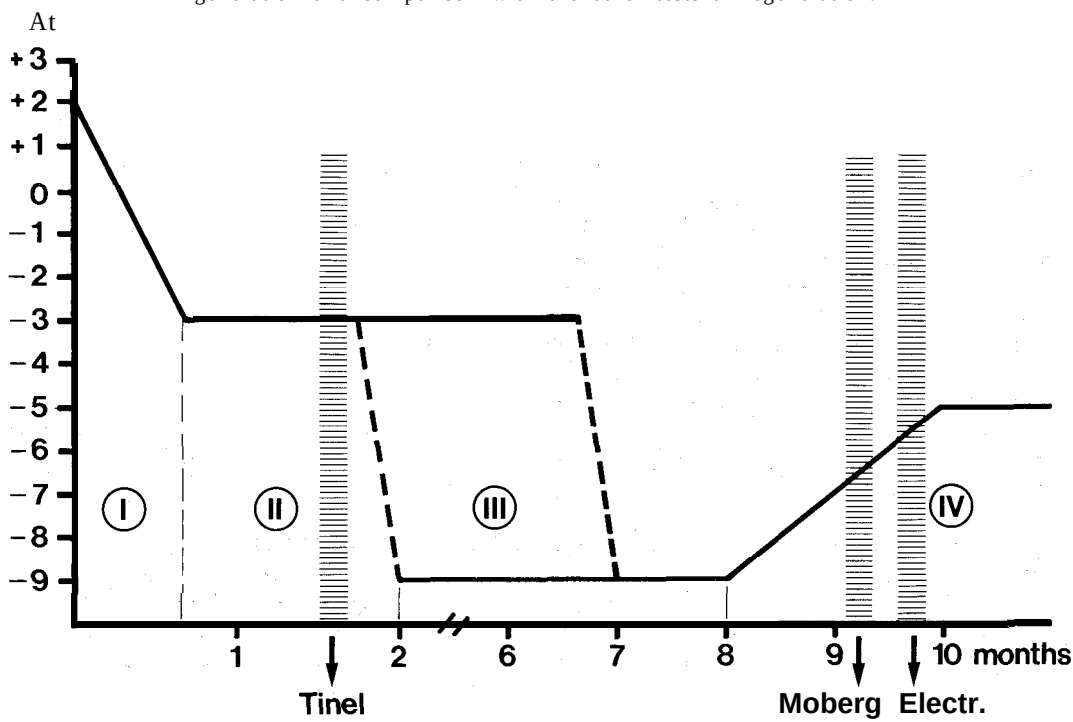
The thermographic follow-up of the normal nervous regeneration (6 cases on 8 = 75%) makes possible the identification of 4 typical phases (Table III):

a) Hyperthermal phase: this appears immediately after the traumatism. It is characterized by a hyperthermia of 2-3 °C in the territory of nerve distribution due to the peripheric vasodilatation caused by the section of the sympathetic nervous fibers (Fig. 3A).

It lasts 20 days and it is during this period of time that neuroraphy occurs.

b) Hypothermal phase: this corresponds to the beginning of the nervous regeneration. It is characterized by a hypothermia of about

Tab. III. Nervous section of the forearm: graph of the thermal modifications during normal nervous regeneration and comparison with the other tests af regeneration.



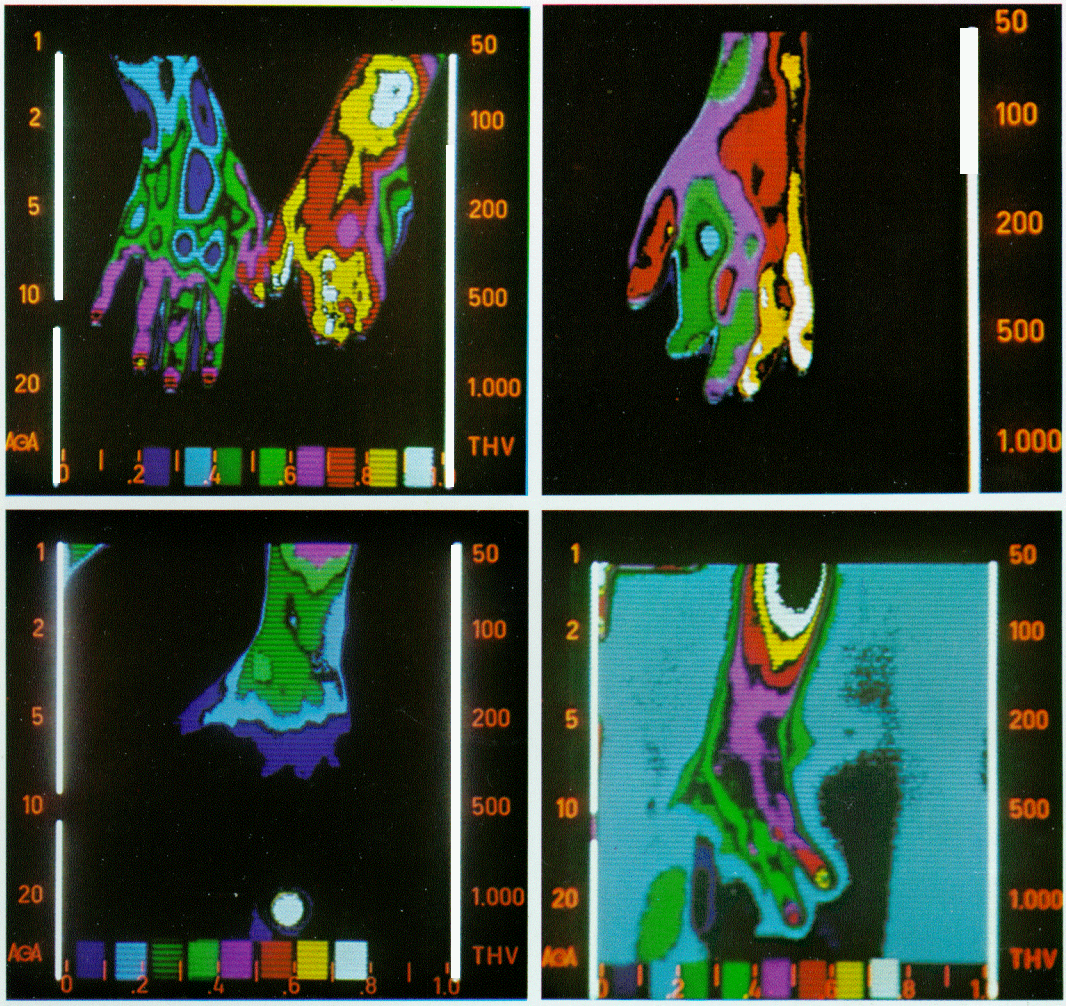


Fig. 3 A-B-C-D Case 3. (A) Section of the left median nerve: diffuaed hyperthermia of the hand (1st thermographic phase). (B) Control 40 days after the section, after neuroraphia: hypothermia of the territory of distribution of the median ncrve (2nd thermographic phase). (C) 3 months after the nervous section: thermal amputation of the hand (3rd thermographic phase). Nervous regeneration took place regularly. (D) 6 months after the nervous section: hypothermia of the 2nd and 3rd fingers which remained unchanged (4th thermographic phase).

3 °C in the territory of nerve distribution. Hypothermia is due to autonomous vascular spasms. Its duration depends on the site of the nervous interruption (Fig. 3B). The Tine1 sign appears during this phase.

c) Thermal amputation phase: this can be considered the objective sign of normal regeneration. It is characterized by a thermal amputation, involving all the hand, due to vascular peripheral spasms caused by the prevailing action of the sympathetic. It lasts 2 - 3 months (Fig. 3C).

d) Stabilization phase: this corresponds to the end of nervous regeneration. Hypothermia decreases slowly and stops at values of LTG of about 5 °C. It is a persistent and irreversible consequence of the lesion (Fig. 3D). At the beginning of this phase the Moberg test and the electromyography become positive and thermic and tactile sensitivity

reappears. Later the discriminative sensitivity also reappears.

3. Abnormal nervous regeneration; thermographic patterns

In 2 cases out of 8 (25%) nervous regeneration was abnormal. The first 2 thermographic phases took place regularly; and the Tine1 sign appeared. However the large thermic fall typical of the third thermographic phase failed to take place and unfavourable clinical developments made a surgical intervention necessary.

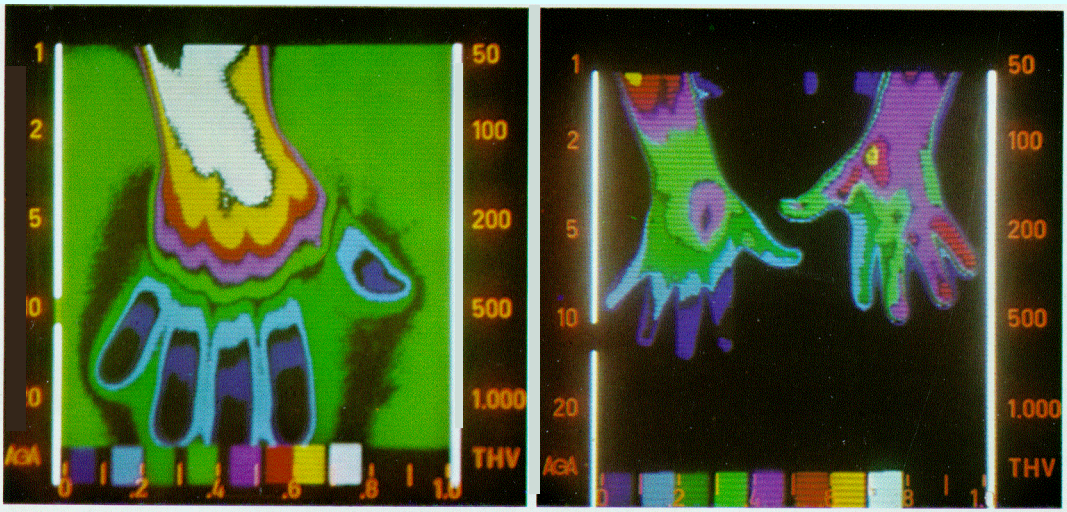


Fig. 4 A-B *Case 4.* Carpal tunnel syndrome. (A) Preoperative thermography: thermic amputation of the hand. (B) Control 10 days after decompressive surgery: reduction of hypothermia ($\triangle t = 4\,^{\circ}C$).

The third thermographic phase however represents the decisive development which demonstrates normal nervous regeneration. One must stress that thermographic data are more precocious than others and therefore of greater value than other tests used up to this time. The results of thermography in fact precede by nearly three months electromyography and the Moberg test which were hitherto regarded as the most effective.

The lack of a thermic fall at the moment at which it should appear represents therefore a secure indication of the need for surgery; which being based on thermographic evidence is more timely, and therefore offers a better chance of functional recovery.

B) Non traumatic compressive nervous lesions (carpal tunnel syndrome)

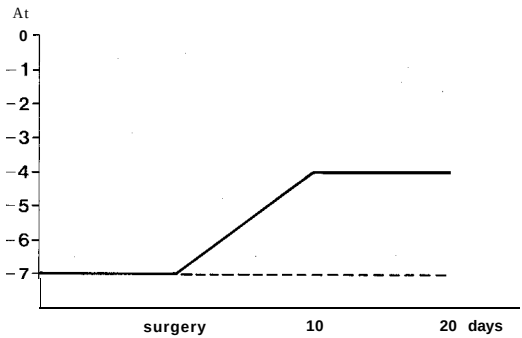
The carpal tunnel syndrome with the exception of cases taken in the earliest phases, in which medical therapy can be attempted, always requires surgery (decompression with or without neurolysis). However recent lesions, that is those of less than 6 months, are those which respond best to surgical treatment.

The clinical problem. In recent lesions that have been subject to decompressive surgery the clinical problem is to evaluate the post-operative phase, and to recognize, in cases in which there has not been a clinical improvement, the cause of the failure. It is precisely in this situation that thermography allows one to establish if surgery is necessary once again or if, on the other hand, conservative treatment is sufficient. Twenty-one patients in the first stages of carpal tunnel syndrome were subjected to thermography.

The thermographic examination took place before surgical intervention and every 5 days after the operation.

Pre-operative thermographic data is extre-

'Tab. IV. Carpal tunnel syndrome: graph of the post-operative thermographic modifications in cases of success (-) and failure (--------) of surgical interventions-.



mely important for comparison with that which is post-operative. In all patients a hypothermia equal or superior to 5 °C, and covering all the hand, was registered before the operation; and this was due to a marked vasoconstriction consequent .upon a sympathetic ipertonia caused by compressive irritation.

Post-operative control (after 10 days) showed in 81% of the cases (17 out of 21) the disappearance of clinical symptoms (parhestesia; stiffness) with constant reduction of hypothermia to the value of 3-4 °C (Fig. 4; Table IV). In the remaining 19% of the cases (4 out of 21) the pain remained unchanged after the operation.

In this group however thermography gave different results. In 3 out of 4 cases the thermographic behaviour was similar to that encountered in patients who showed improvement as a result of surgery namely the hypothermia was reduced (Table V). These patients treated with physiokinesitherapy showed a marked clinical improvement.

In 1 case out of 4 on the other hand no modification either clinical or thermographical was noted. This patient did not improve with physiokinesitherapy. Another surgical operation was therefore required. It is evident therefore that an unchanged post-operative thermographic pattern reveals the failure of surgical intervention.

So thermography enables one to distinguish between the cases which should be treated by renewed surgery and those which can be improved by conservative treatment.

Tab. V. Carpal tunnel syndrome: results of surgical intervention in 21 cases treated with decompressive surgery with or without neurolysis.

	Unchanged hypothermia	*Reduced hypothermia*
Disappearance of symptoms	-	*17 (81%)*
Persistence of symptoms	*1 (4,7%)*	*3 (14,3%)*

III OSTEQ-AR'IICULAR DISEASES
(Sudeck-Léricbe atrophy)

In the osteo-articular pathology of the hand, Sudeck-Leriche atrophy is certainly the disease most closely linked to grave vascular disturbances. The new therapeutic possibilities offered by calcitonin give it therefore a particular importance[3]. Not all Sudeck-Leriche patients improve with calcitonin and it is not possible to know beforehand what the different responses will be. Thermography gives us this possibility however and one can therefore avoid a long and costly treatment by drugs. Thermography also enables us, as in other types of osteo-articular pathology such as rheumatoid arthritis and Paget's disease, to evaluate the effectiveness of the treatment [4, 5, 7, 8].

Twenty one patients with Sudeck-Leriche atrophy have been studied by thermography: all the patients observed presented a typical clinical picture (pain, functional limitations, oedema, distrophy of the skin and the nails, localized osteoporosis). All the patients were treated with porcine calcitonin (160 u. per day for 20 day). The thermographic controls were carried out before therapy and every ten days during and after therapy.

Basal thermography. Initial thermography has made possible the distinction of 2 groups.

The first group consists of patients with basal hyperthermia equal or superior to 2 °C on the injured side: this group may be defined as << warm-Sudeck >> and represents 76% of the patients with Sudeck atrophy. The second group consists of patients with hypothermia of the injured hand equal or superior to 2 "C. This group may be defined as << cold-Sudeck » and represents 24% of the patients.

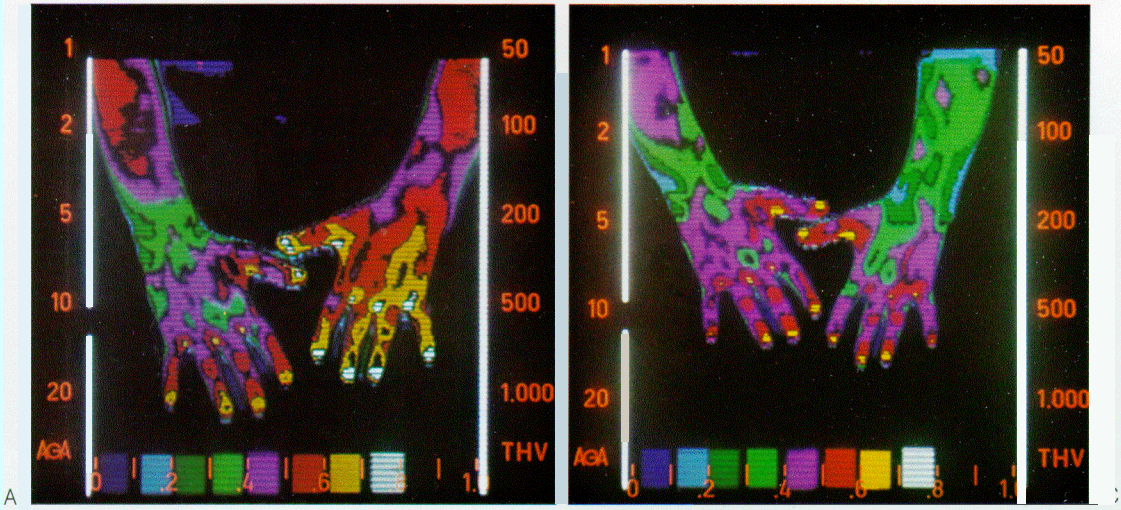


Fig 5 A-B-C. Case 5. Warm-Sudeck in left hand. (A) Diffused hyperthermia of the injuried hand (At = 2 “C). (B) Radiographic pattern: diffused osteoporosis. (C) Control at the end of the treatment cycle (20 days) with calcitonin: regularisation of thermic distribution.

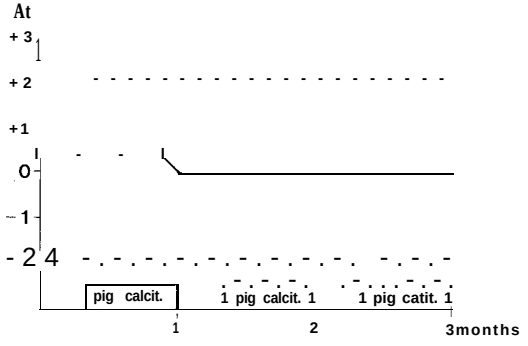
Valuation of the effects of therapy: thermographic patferns. The preceding distinction has shown itself to be of fundamental importance as a result of treatment with calcitonin: the two groups in fact responded to therapy in markedly different ways (Table VI).

n) In the first group, warm-&deck, therapy gave the following results: in 81% of the cases there was a constant noticeable clinical improvement with normalisation of the thermographic pattern (Fig. 5). These results took place after no more than a single calcitonin

Tab. VI. **Sudeck-Léricbe atrophy. Results of treatment** with calcitonine in cases of warm&deck (16 cases = 76%) and of cold-Sudeck (5 cases = **24%).**

	Cured	*Unchanged*
Warm-Sudeck	13	**3**
Cold-Sudcck	-	**5**

Tab. VII. **Sudeck-Léricbe atrophy: graph of the** thermic modifications with calcitonin treatment. Warm-Sudeck: cured cases (-); no cured cases (-------). Cold-Sdeck: no results (.-.-.-.).



cycle. In the remaining 19% of the cases there was no clinical improvement: the thermography remained unchanged (Table VII).

b) In the second group, cold-Sudeck, calcitonine therapy led to no clinical improvement nor to any thermographic modifications. The hypothermia pattern also remained unchanged after several calcitonin cycles.

Pathogenetic considerations. The existence of 2 thermographic groups of Sudeck-Leriche atrophy confirms the validity of the 2 principal pathogenetic theories of this disease: the Leriche-Policard theory according to which demineralisation is a result of a reflex-hyperemia which corresponds to warm-Sudeck; and the theory of Fontaine according to which the demineralisation is due to venous stoppage: which corresponds to cold-Sudeck. But over and beyond these pathogenetic considerations one must stress that, in practice, thermographic data enables one to choose, from the start, the patients with Sudeck atrophy which may be effectively treated with calcitonin.

CONCLUSIONS

The hand represents a zone particularly well adapted to thermographic study.

As in other zones thermography can give several differing indications:

1. diagnostic, as in vibrating tools angiopathy;
2. prognostic, as in vascular or nervous traumatic lesions or in Sudeck atrophy.

Thermography, furthermore, can give important contributions to a correct valuation of the effectiveness of medical treatment (Sudeck atrophy) or of surgery (Carpal tunnel syndrome). The simplicity and speed of execution, the complete harmlessness and the importance of the information obtained make this a method that may be very properly used.

REFERENCES

1. ACCIARRI L., CARNEVALE F., DELLA SELVA A.: Thermography in the hand angiopathy from vibrating tools. *Acta Thermographica*, **1**, 18-28, 1976.
2. BAUDET J., LE TREUT A., DILHUYDY M. M., GOUMAIN A. J. M.: Valeur pronostique de la thermographie dans les interventions de réimplantation ou de sauvetage des membres. *J. Radiol. Electrol.*, **55**, 239-242, 1974.
3. DE BASTIANI G., NOGARIN L., PERUSI M.: La calcitonina porcina nel trattamento delle osteoporosi localizzate. *Gior. It. Ort. Traumat.*, **2**, 181-190, 1976.
4. HESSLER C., BURCKHARDT P.: La téléthermographie dans le traitement de la maladie de Paget par la calcitonine humaine. *Méditerranée Médicale*, **111**, 15-17, 1976.
5. NAJA A., LÉCINE A., FOURNIÉ A., AMIGUES H., ROQUES C.: La téléthermographie dynamiques, test objectif dans la surveillance des maladies de Paget traitées par la calcitonine. *Méditerranée Médicale*, **2**, 105-107, 1973.
6. PRATS ESTEVE M., VIDAL-LOPEZ F., PUIGDOMENECH ARISA L., PUIG TORO E. M.: La téléthermographie dynamique dans le côntrole du blocage sympathique du membre superieur. *Méditerranée Médicale*, **111**, 5-6, 1976.
7. RING E. F. J.: Thermography and rheumatic diseases. *Bibl. Radiol.*, **6**, 97-106, 1975.
8. RING E. F. J.: Thermographic evaluation of calcitonin therapy in Paget's disease of the tibia. *Acta Thermographica*, **1**, 67-72, 1976.
9. WEILL F., AGACHE P., BIDARD DE LA NOÉ A. M., BARALE J., RICATTE J. P.: Sémeiologie thermographique des affections vasculaires des extrémités supérieures. *Sem. Hôp. Paris*, **47**, 1230-1238, 1971.