ORIGINAL PAPERS

Thermography in malignant thyroid nodules

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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.

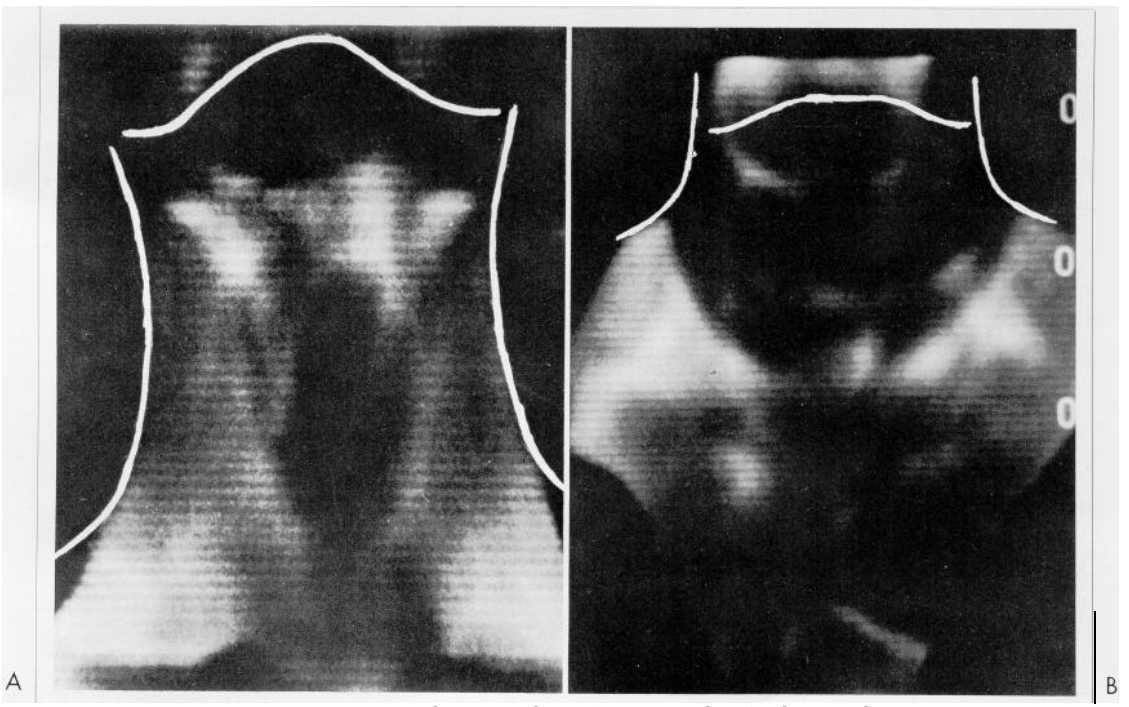

Fig. 1. Normal thermography: A) Long neck. B) Short neck.

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.

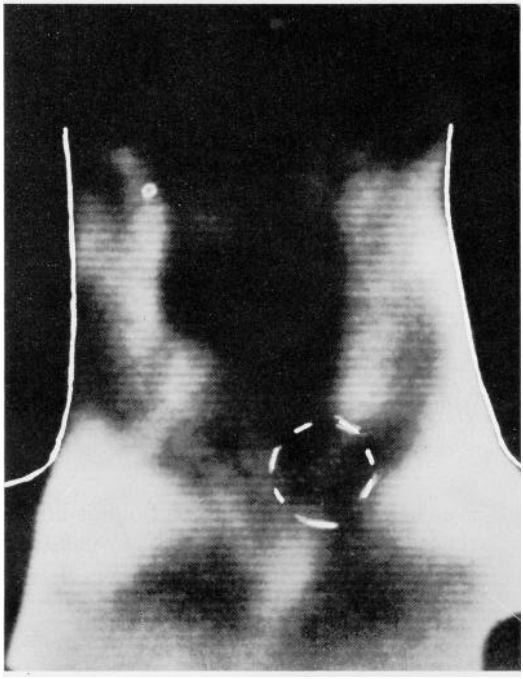

Fig. 2. Left nodule 2 months old, 4 cm in diameter. The nodule's area is cold but above and below there is a thick hot line like a vascular course. (T_1 type).

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;

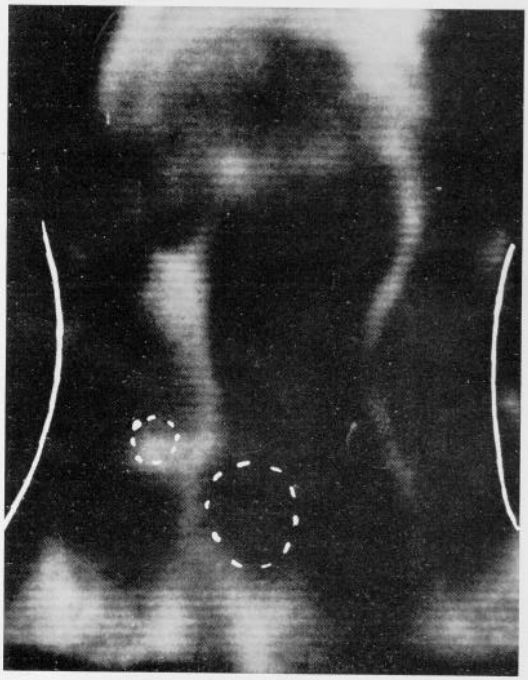

Fig. 3. Two nodules 1 month old, encircled. The right superior nodule is hot, with a marked vascular course on the right side. The isthmic nodule is cold. The right nodule was a follicular microcarcinoma (sclerosing-occult). The inferior nodule was a benign adenoma. (T_2 type).

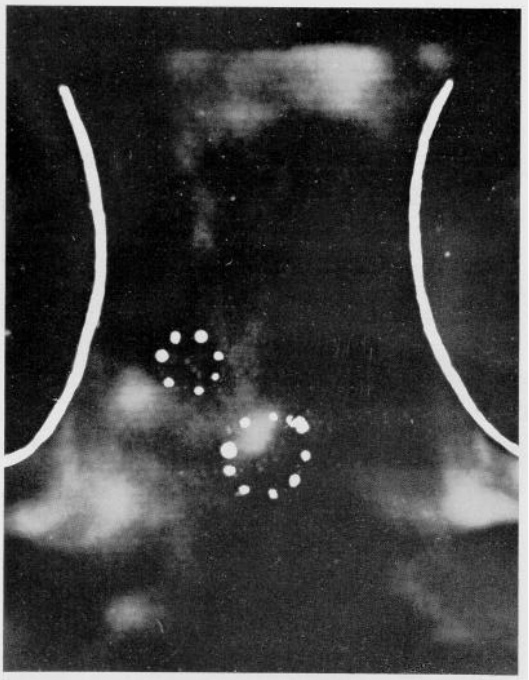

Fig. 4. Two nodules. The nodule on the right is old. The isthmic nodule is recent. (3 cm diameter). Both were cold at the radionuclide scan. Thermogram shows a hot spot on the isthmic nodule, the rest is cold. The hot spot is associated with a hot vascular pattern. Histology: the nodule on the right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

- 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 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.

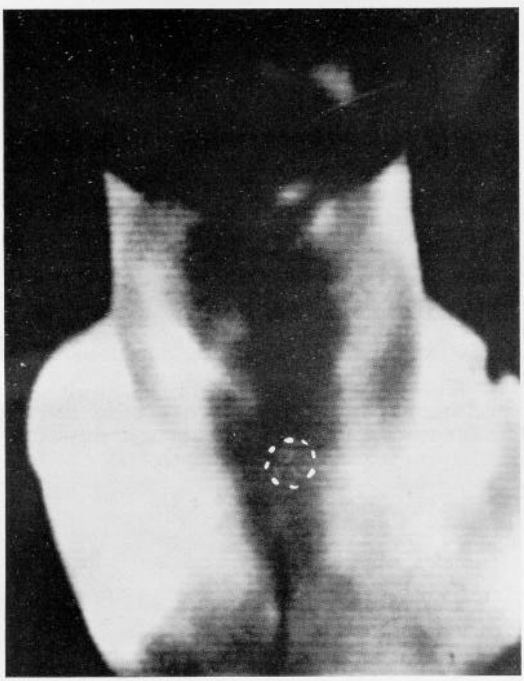

Fig. 5. Isthmic nodule 1.5 cm 1 month old. Thermic asymmetry. Star like image on the right side at a distance from the nodule which was pretracheal. Histology: papillary carcinoma. (T_3 type).

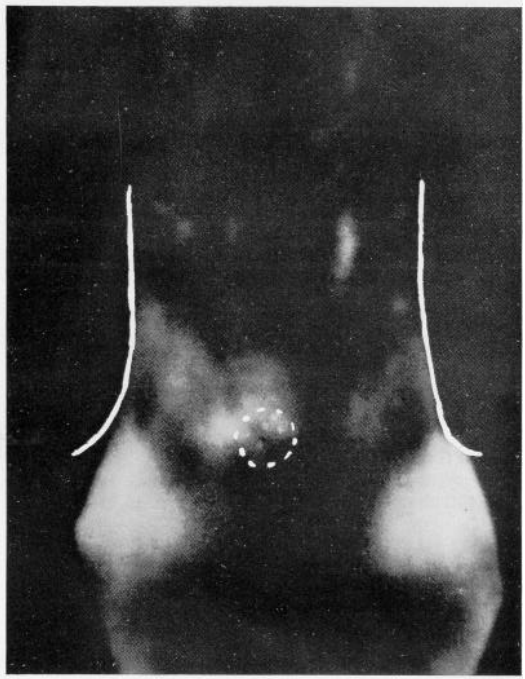

Fig. 6. Right superior nodule, 1 year old, with a 2.5 diameter and lymph nodes. Heterogeneous thermic image larger than the nodule area. (T_3 type).

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 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 cancer'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	T_0	**Totale**
Cancer	22	10	11	5	4	52
Benign nodule	14	17	44	62	168	305
Potential malignancy		2	5		7	

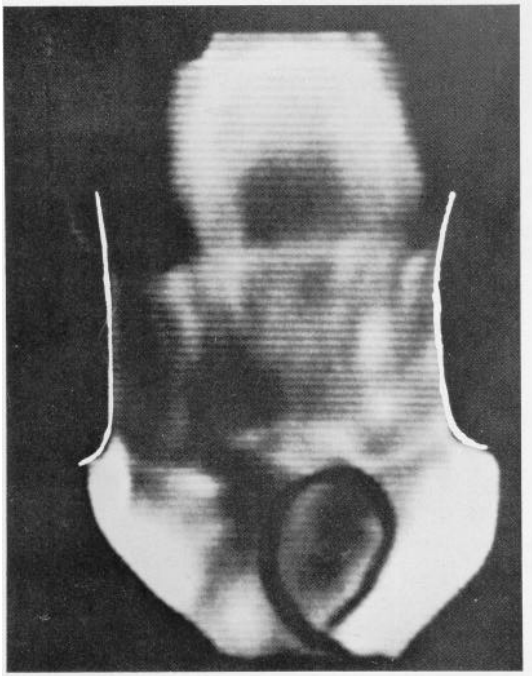

Fig. 7. 71 year old patient, already operated for a benign adenoma, second nodule with a 3 cm diameter, appeared 1 month before the examination. Nodule's area is cold, encircled with heat, plus large heterogeneous hyperthermic area covering half the neck. Histology: undifferentiated carcinoma. (T_4 type).

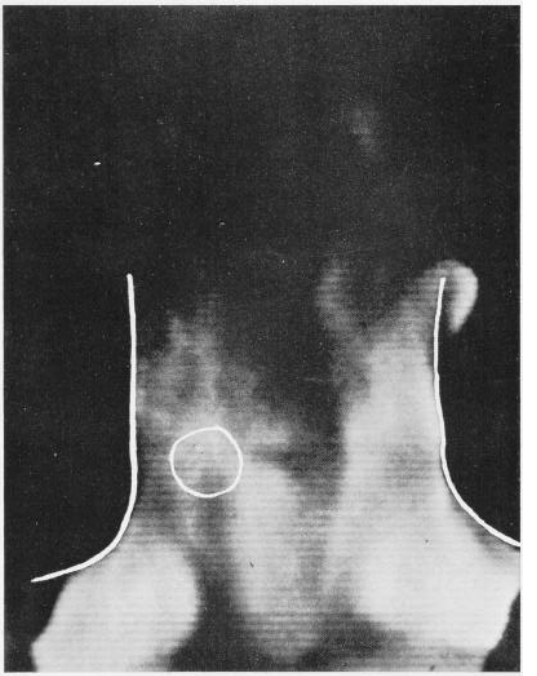

Fig. 8. Right nodule, 3 weeks old, with a 2 cm diameter. Star like hyperthermic image spreading far beyond the nodule. Histology: medullary carcinoma. (T_4 type).

Tab. VI. **Thermographic correlations.**

Nodule's diameter	***Number*** of cases	
	T_3 or T_4	T_0, T_1, T_2
D≤10 mm	4	11
D≥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	2
cancer, with a 4 to 6 mm diameter, associated to an adenoma	1
a 5 mm in diameter cancer at the boundary of a cyst	2
cystic cancerous nodules with a 9 mm diameter	1
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	3
— partially cystic	3
— solid	

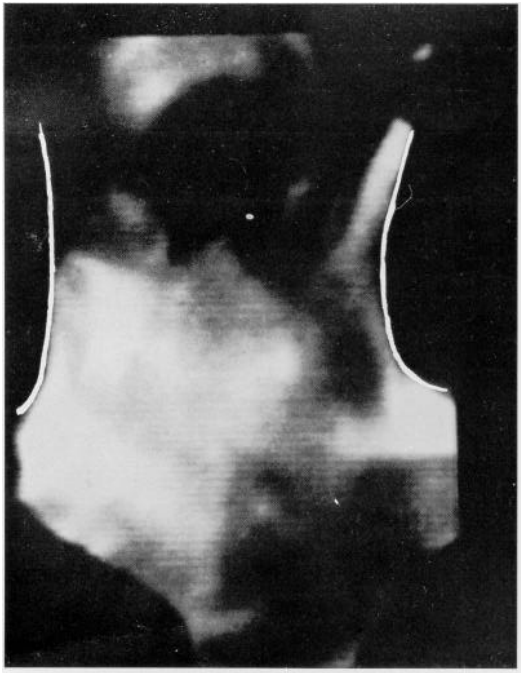

Fig. 9. Multinodular goitre 1 year old, with lymph nodes on the right side. 5 nodules isotopically cold. Thermogramm: large hyperthermic heterogeneous area. Histology: polymorph carcinoma. (T_4 type).

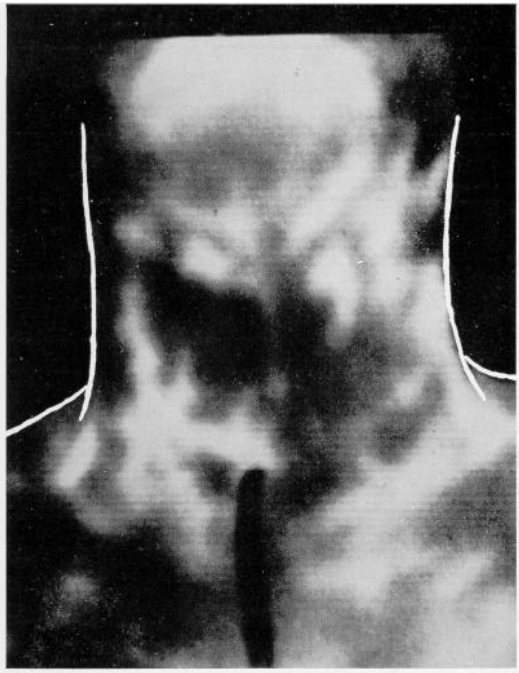

Fig. 10. Multiheteronodular goitre with signs of hyperfunction. Heterogeneous isotopic scan, with increased uptake on one nodular area. Thermogramm: high degree of hyperthermy on both sides, anarchic aspect. Histology: papillar and follicular carcinoma developed in a multiheteronodular goitre plus lymph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

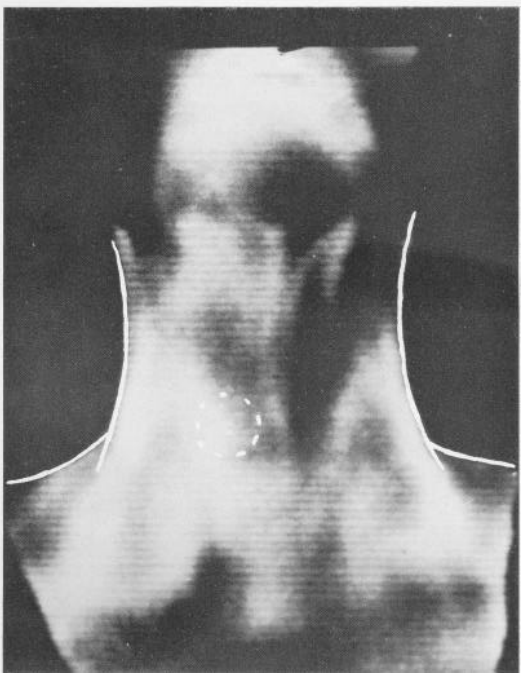

Fig. 11. 1 month old nodule in the inferior part of the right lobe, with a 2.5 cm diameter. No lymph nodes. Large heterogeneous hyperthermic area on the right side plus vascular course. Histology: mixed papillar and follicular carcinoma. (T_4 type).

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.

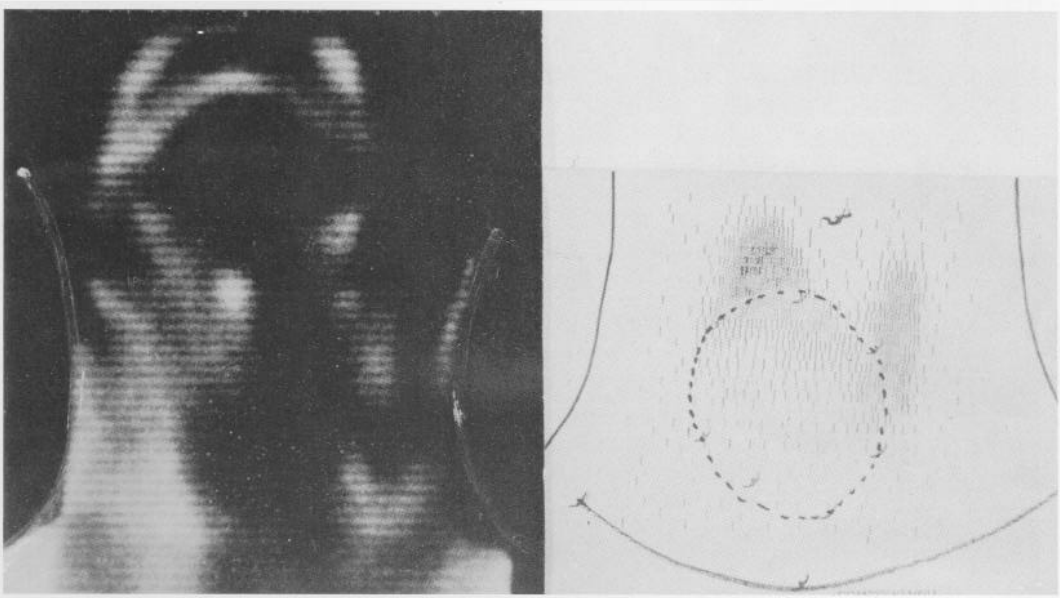

Fig. 12. Hyperthermic adenoma; hyperthermy is moderate compared to the size of the adenoma. encircled on the scan.

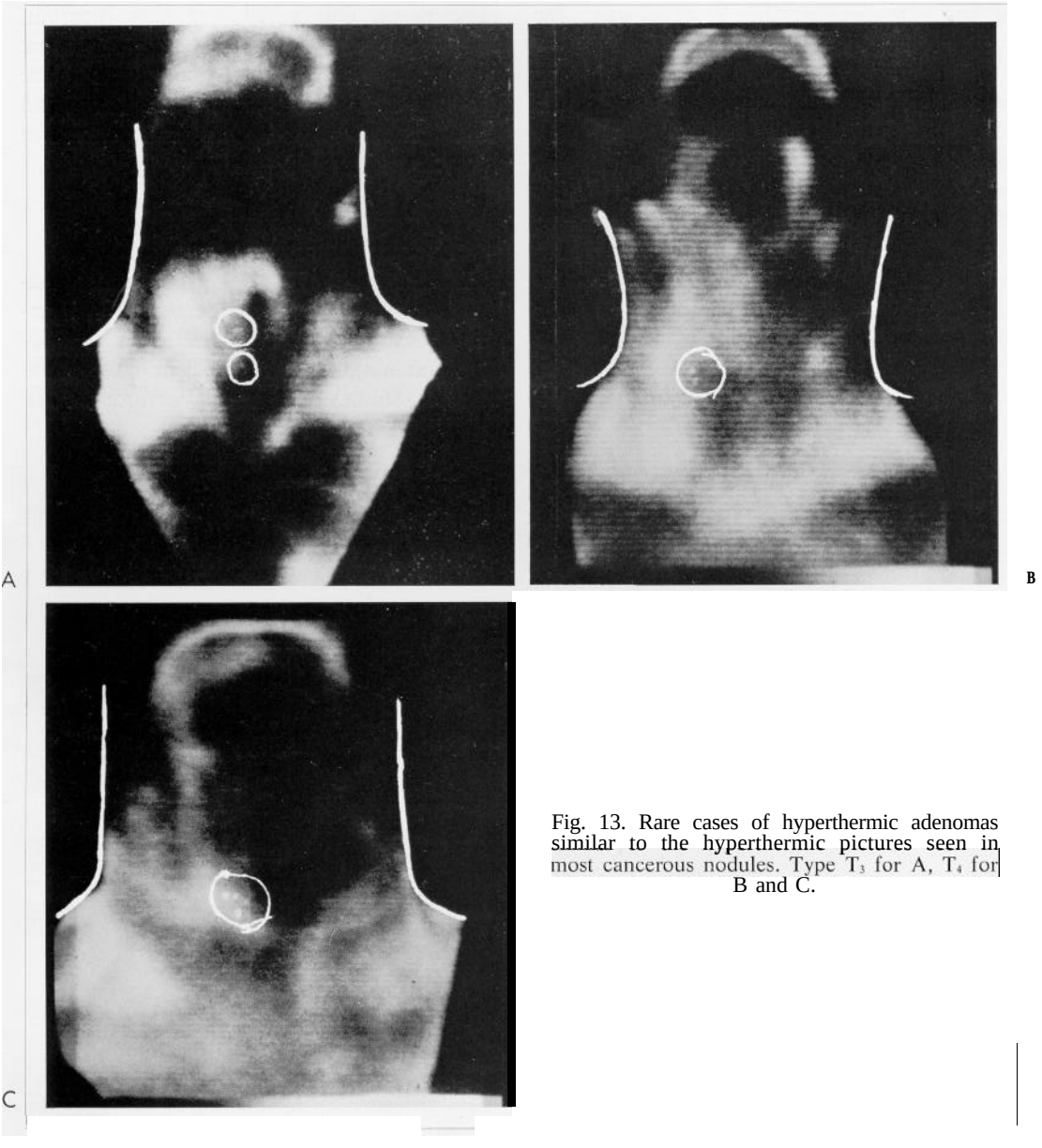

Fig. 13. Rare cases of hyperthermic adenomas similar to the hyperthermic pictures seen in most cancerous nodules. Type T_3 for A, T_4 for B and C.

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.

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