Thermographic studies of the normal back and of spinal lesions

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SUMMARY. The normal tbermograpic pattern of the back and spine is composed of a variety of individual temperature distributions. Although only rarely one thermogram equals another certain predominant patterns for particular regions do exist. Asymmetries of symmetrical portions and marked localized differences of the thermal map in follow-up examinations are occasionallv found.
In spinal lesions thermography did not prove to be of diagnosiic importance. One exception might be the cervical disk berniation witb pathological findings in 5597 of cases.

Key words: Thermography; skin temperature; normal back thermogram; lumbar/ cervical disk herniation; intraspinal tumor; syringomyelia; spinal trauma.

The value of infra-red thermography in the diagnosis of lesions of the spinal cord and adjacent structures has not yet been fully assessed. Earlier studies indicated thermography to be as accurate as myelography in demonstrating herniated lumbar disks [10] whereas other studies showed it to be of no diagnostic value owing to only occasional abnormal heat patterns 13, 14. Other pathological conditions of the spine and spinal cord have not, as yet, been subjects of controversal discussions since they have not been sufficiently studied; the same applies to the description of normal back thermograms in healthy individuals, being basic for the recognition of pathology.

The present study was therefore undertaken to investigate the heat pattern of the normal back and to determine if the non-invasive technique of thermography might be successfully applied for the evaluation of lesions of the spinal cord, its sheaths and nerve roots.

METHODS

Thermograms of the back were carried out in a total of 113 patients from a neurological and psychiatric clinic. Fifty-eight of these were physically healthy and served as controls. The remaining 55 patients had signs and symptoms suggesting spinal lesions:

- 22 lumbar or cervical herniated disks
- 19 intraspinal tumors
- 6 syringomyeiia
- 4 metastases or haemangioma of vertebrae
- 4 traumatic lesions

44 of these patients had myelography, 9 patients were operated.

A Barnes-Old Delft infra-red thermograph was used. Additional instrumentation consisted of a thermal grey scale, a thermoscope and a thermography analyzer for densitometric analysis (for technical details see ref [1, 2, 4, 5]). Thermography was performed at 20°C in an adequately thermostable room. The skin temperature was allowed to adapt to the room temperature for 20 min. Investigations were usually performed in the sitting position which resulted in an overall view of the whole back (Fig. 1). Sometimes, detailed-or magnification-thermograms were made with the patient prone using a mirror.

For better orientation pea-sized isothermic metal foil markers placed on the skin were used to indicate various topographic landmarks of the superficial anatomy.

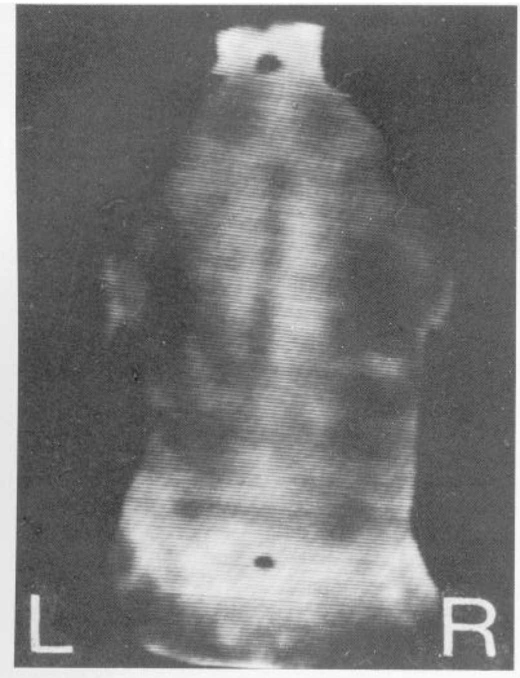

Fig. 1. Normal back thermogram of a 35year-old female. Small isothermic metal foil at spinous process of C7 and L4. The outer contours of the body are readily detectable. Marked temperature niveau at the cervico-thoracic transition. The upper l/3 of the thoracic spine presents as a midline warm stripe, the lower 2/3 as a cold stripe in comparison to adjacent lateral structures. << Restless B temperature distribution overlying the lumbar spine and lumbar region in this case of cellulitis.

In the thermogram the lighter tones of grey represent warmer areas and the darker tones indicate cooler areas. By use of the grey scale quantitative temperature determinations could be performed. Skin temperatures of 31°C and less were termed << cold >>, of 32°C << midwarm >>, of 33-34°C << warm >> and of 35°C and more << hot >>.

RESULTS

Normal thermogram of the spine and back

A normal thermogram reveals physiological warmer and cooler areas depending, for instance, on the arterial vascularisation, on the amount of hair or of subcutaneous fat deposits. Besides these consistencies considerable temperature variations on the back are observed between different healthy individuals and also when reinvestigated after a time interval1 in the same individual.

The multiplicity of possible thermographic patterns necessitated the introduction of certain terms. Almost always rather c< circular >> areas with a diameter of usually l/2 to 2 vertebrae are found. In the centr: they may be up to 2°C above or below the environmental temperature. These (< circulars >) may be poorly outlined with a gradual temperature transition - either increasing or decreasing - towards the periphery. Alternatively they may be sharply delineated from adjacent areas with abrupt temperature changes. Hot <(circulars >> may have a cooler rim, but the converse has not been observed. Furthermore cold or hot areas of rhomboidshape or oval configuration have been found with the axes either longitudinal or

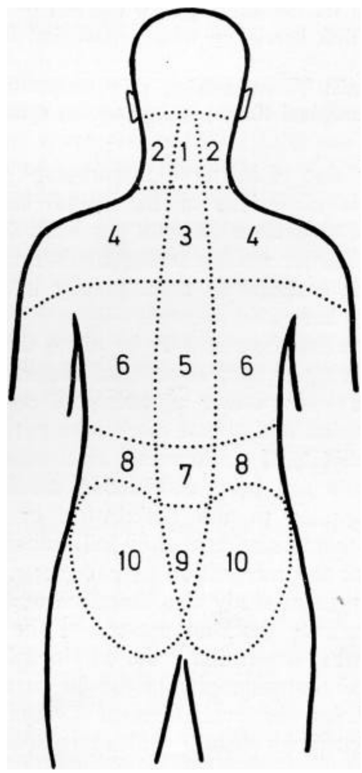

Fig. 2. Subdivision of the back thermogram into 10 different regions according to anatomical features. (1) cervical spine, (2) dorsal neck region, (3) thoracic spine, cranial l/3, (4) shoulder region, (5) thoracic spine, caudal 2/3, (6) dorsal thoracic region, (7) lumbar spine, (8) lumbar region, (9) sacrum, (10) gluteal region.

transverse, but very rarely oblique. They were always sharply defined with respect to temperature differences. We called a << restless region D one in which a larger area contained within it several small cold, warm and hot spots with an overall temperature difference of up to 2°C (Fig. 1). Frequently, but not always, the underlying process was a cellulitis with or without adipositis 16.

Topographic evaluation of the thermal map

For more precise description of the regional differences in the thermogram of the back and spine, the area under investigation has been subdivided into 10 different regions (Fig. 2).

Cervical spine and dorsal neck region (Fig. 3)

In all observations the skin temperature of the dorsal neck region was warm, mostly symmetrically distributed, and sometimes increasing gradually from medial to lateral or decreasing from cranial to caudal, both occurring in 13% of cases. In 79% of cases no difference was observed between the skin overlying the cervical processes and more lateral segments. In the remaining 21%, this area appeared as a longitudinal stripe which was slightly warmer or cooler than the adjacent structures. This stripe sometimes involved only the upper or the lower half of the cervical spine with a temperature level which is not explained by the

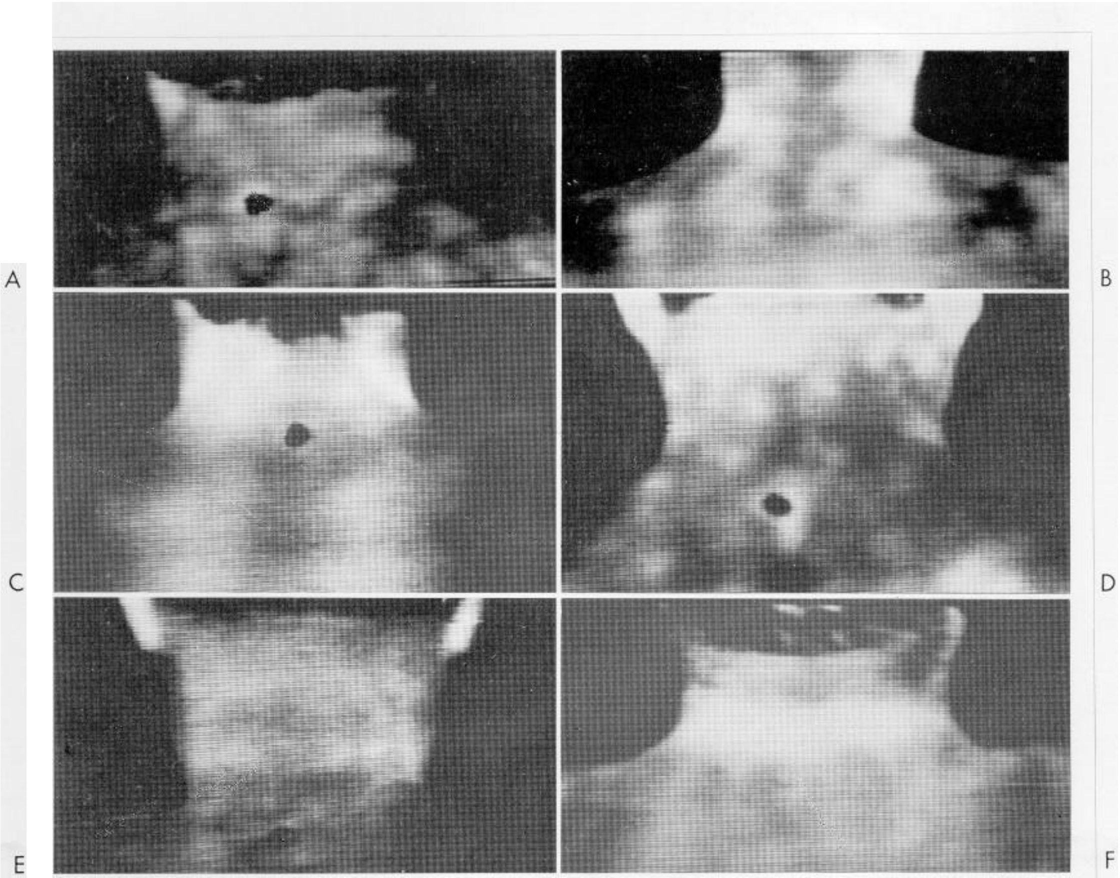

Fig. 3 A-B-C-D-E-F. Normal thermograms ol the neck. (A) Skin temperature overlying the cervical spinous processes identical with lateral masses; metal foil at spinous process of C7; (B) cervical spine presents as a cool midline stripe; (C) symmetrical temperature increase from medial to lateral and (D) decrease from cranial to caudal. Midline hot circular above C7 well demarcated; (E) temperature niveau with abrupt temperature decrease in the lower cervical l/3; (F) << bull-neck >> with annular hot band well delineated in either direction, representing skin fold.

anatomical configuration. One exception is a spot overlying the spinous process of C7 and occasionally also of C6; this may be colder than the rest of the cervical region or the neck, or more rarely may be a circular, well circumscribed hot area. One patient presented two nearly identical bilateral paramedian cold circular spots, which were well delineated and did not correspond to any morphological features.

Thoracic spine, shoulder and dorsal thoracic region (Fig. 4)

The thoracic spine has been separated into a cranial and two caudal thirds because of frequently encountered differences in temperature distribution (Fig. 1). In 46% of cases the skin temperature overlying the spinous processes of the upper thoracic portion was not contrasted to the more lateral segments. It ap-

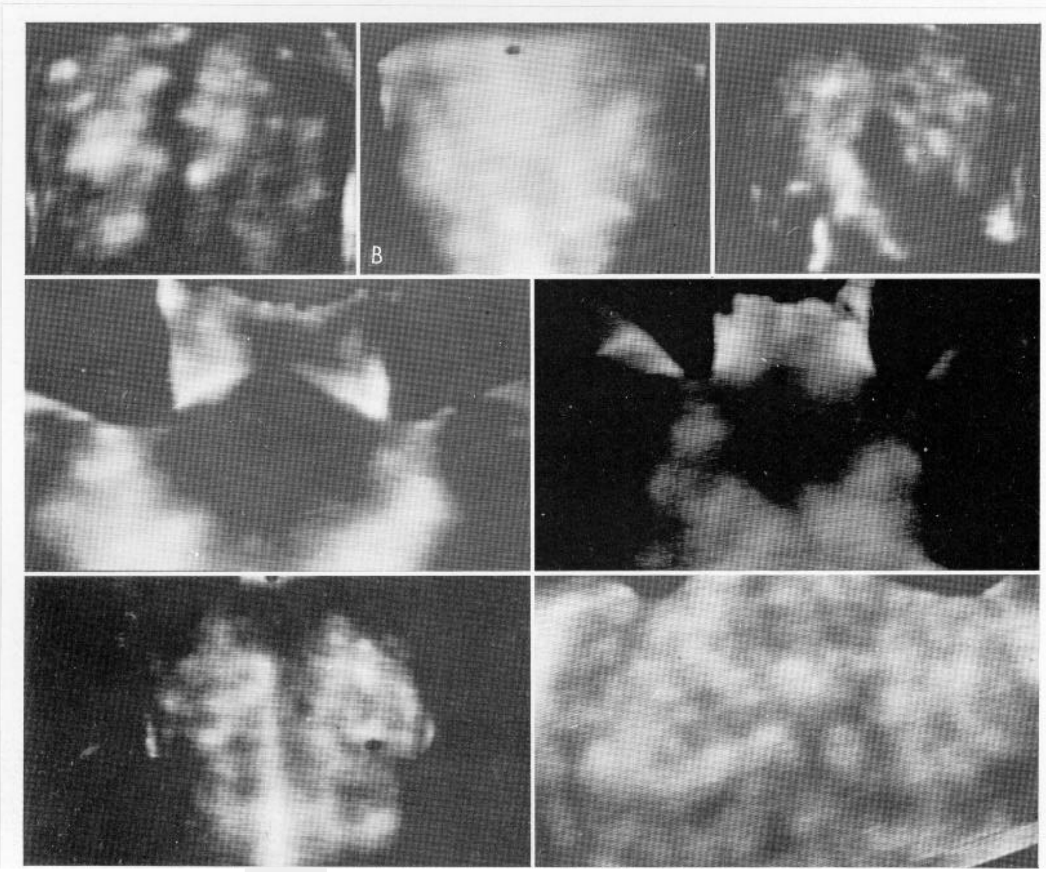

Fig. 4 A-B-C-D-E-F-G. Normal thermograms of the thoracic back. (A) Zig-zag-shaped cold midline stripe overlying the spinous processes of the thoracic spine; (B) symmetrical skin temperature distribution with the spine not contrasting to the surroundings; (C) comma-shaped hot stripe paramedian to the lower thoracic spine; (D) cold midline rhombus-shaped zone at the cervico-thoracic junction and (E) triangular zone at the upper thoracic spine, anatomically possibly correlating with the so-called << lime-leaf tendon “; (F) hot poorly-outlined circulars overlying the inferior angle of the shoulder blades, on the right marked with a metal foil; (G) bilaterally and symmetrically distributed c< restless areas >> comprising the whole thoracic back with multiple temperature differences up to 2’C without apparent adipositas. Note the enormous difference in the thermal pattern between Fig. 4B and 4D in repeat thermograms of the same individual taken with a time interval of 2 weeks.

peared as a colder stripe in 43% of cases, usually straight or zig-zag-shaped; more rarely this was hour-glass shaped. In only 11% was this segment warmer (Fig. 1). On a few thermograms a cold, rather rhombus shaped or triangular zone was noted; this was situated in the midline of the upper thoracic region and occasionally included the lower cervical region. The anatomical correlation could be the so-called << lime-leaf tendon >>. The skin temperature of the lower 2/3 of the thoracic spine was similar to the surroundings in 23y0 of cases (Fig.!jF),warmer in 35% (Fig. 5C,D) and cooler in 12% (Fig. 1). In the remaining 30%

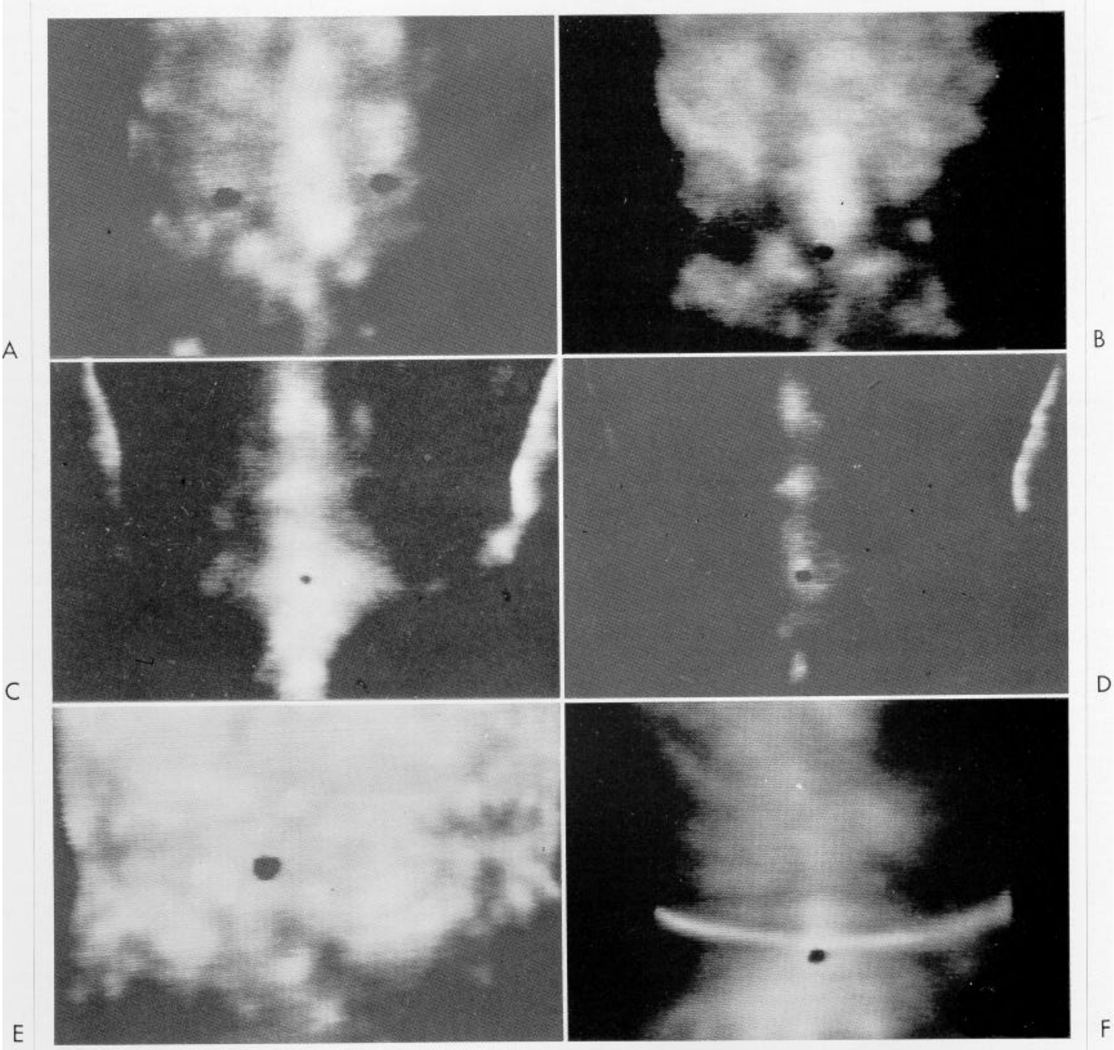

Fig. 5 A-5-C-D-E-F. Normal thermograms ol" the lumbar back. (A) Hot midline stripe with a cold border zone overlying the lumbar spine, bilaterally placed metal foils indicate posterior iliac crest; (B) temperature difference between upper and lower lumbar spine, L4 is marked by metal foil; (C) hot midline stripe above lumbar and lower thoracic spine without border zone but with marked temperature decrease towards thoracic and lumbar lateral regions; (D) same area as before but with different setting of brightness turning up hour-glass-shaped temperature elevation; (E) lumbar spine not contrasting to lumbar region; (F) annular band of temperature elevation produced by skin fold.

of cases, only the upper or the lower half of this area differed from the adjacent temperatures whereas the other half was identical with more lateral portions. In these latter cases the middle third part of the thoracic spine - if differing - was always cooler, whereas the lower third part could also be warmer. The thermal pattern of the shoulders and lateral thoracic portions was symmetrically distributed in only 314 and 4/5 of cases respectively. The remainder presented local temperature differences up to 1.5"C with one side being colder than the other. The deltoid muscles were usually cold. In the dorsal thoracic portions some strange findings have been observed without any evident anatomical substrate and this makes the interpretation of possible pathological thermograms difficult; examples of these were a hot, poorly outlined circular area overlying an inferior angle of a shoulder blade, bilaterally and symmetrically placed << restless areas >> with multiple temperature differences up to 2°C without apparent adipositas, comma-shaped hot stripes paramedian to the lower thoracic spine and a hot line obliquely traversing one half of the chest. Occasionally, repeat thermograms were performed at various time intervals. A few showed wide temperature deviations from the preceeding investigation as shown in Fig. 4l3 and 4D.

Lumbar spine and lumbar region (Fig. 5)

The normal thermogram of the lumbar spine was fairly uniform. In 90% of cases the pattern consisted of a straight, zig-zag or hourglass-shaped hot vertical area contrasting with the adjacent colder skin surface. A cool median stripe or a temperature not differing from the surroundings both were encountered in only 5% of cases. The lateral segments of the lumbar region appeared more or less symmetrically: in 65% uniformly cold, in 20y$_0$ mid-warm or the temperature decreased slowly from medial to lateral. In only 5% was there a temperature difference between right and left and this was between l-2°C. Warm or hot circulars or (< restless areas >> were occasionally observed and did not indicate pathological conditions (Fig. 1).

Sacrum and gluteal region (Fig. 6)

The sacral region is characterized by the hot intergluteal cleft contrasting with the homogeneously and symmetrically cool protrusion of the buttocks. In only 1 case was a sharply defined hot circular area observed overlying one of the sacro-iliacs. The skin temperature above the sacrum was warmer than the lateral masses in 43% of cases, but in 47y$_0$ no differences with the surroundings were measured.

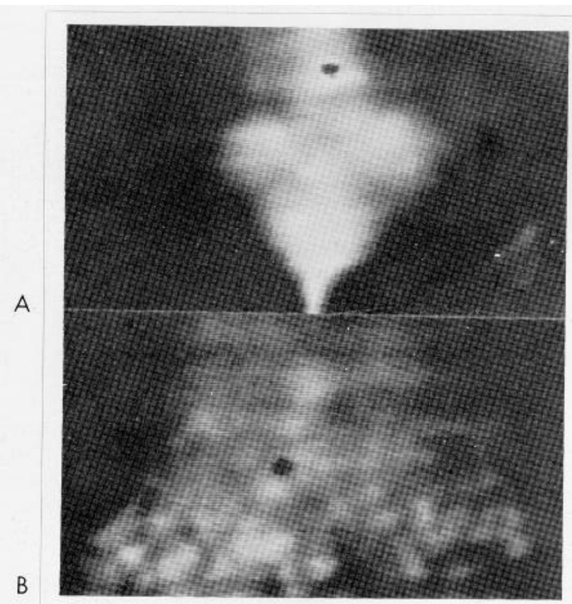

Fig. 6 A-B. Normal thermograms of the lower back. (A) Hot intergluteal cleft below; skin temperature elevation overlying the sacrum. Cold buttocks. L4 is marked bv metal foil: (B) sacrum and gluteal region are not contrasted. << Restless area x symmetrically distributed. Metal foil at interspace L3 - L4.

Herniated lumbar or cervical disks

In 3 out oF 13 patients with neurological symptoms and signs of one or more acutely herniated lumbar disks the thermogram revealed characteristic changes which could be easily separated from normal controls. These changes consisted of a midline circular area which was at least 2°C different from the surroundings and had lobulated processes composed of one or multiple additional hot spots which extended to the affected side. The circulars were rather sharply limited but did not show colder border zones. They were always localized according to the segment involved (Fig. 7, Fig. 8). In 2 additional patients there was a triangular composition of small hot spots on the affected side with the base of the triangle resting on the lumbar spine. The temperature differences usually amounted to less than 2°C. These thermograms were interpreted as questionable although similar findings have not been noted in normals. In 7 of 8 patients with normal thermograms myelography had revealed marked herniation of a lumbar disk between L3 and Sl.

Of 9 patients with characteristic complaints and neurological signs of a cervical disk herniation 5 showed thermographic alterations which consisted of either a sharply limited circular area with an increased temperature of usually 2°C or even more (Fig. 9) or a hot, well-delineated rhombus-shaped area which tended to the site of involvement (Fig. 10) or a hot area with an irregular border zone. Two of the 4 patients with a normal thermogram had myelography; in 1 this indicated a marked unilateral herniation between C7-Thl.

Intraspinal tumors

Nineteen patients with an intra- or extra-

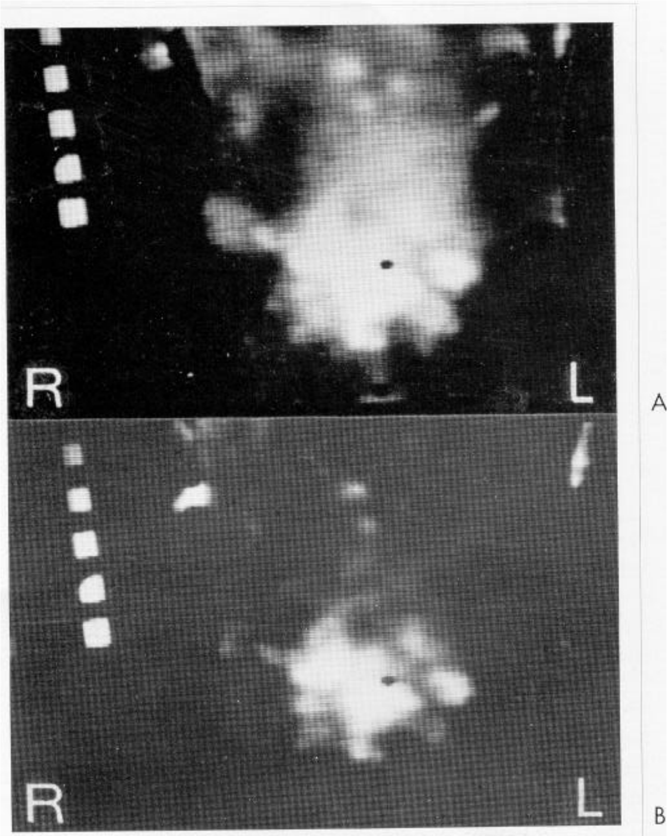

Fig. 7 A-B. Back thermogram in a 54-year-old female with acute right-sidkd intervertebral disk herniation at L3 - L4 level; (A) area composed of multiple confluent spots with elevated temperature centered at L3 - L4 and predominantly to the right side as obvious after different setting of brightness (B). L3 is marked by metal foil.

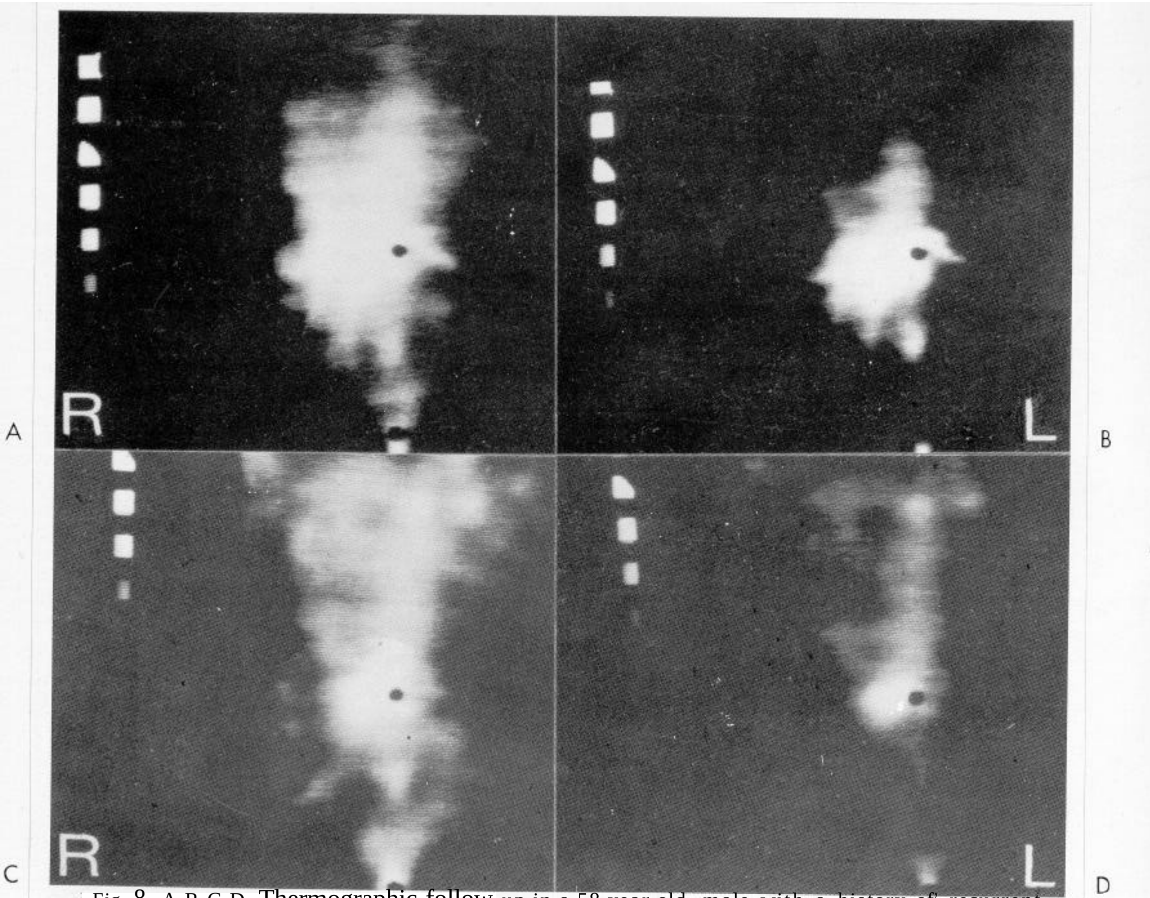

Fig. 8 A-R-C-D. Thermographic follow up in a 58-year-old male with a history of recurrent lumbar disk complaints and acute exacerbation of right-sided symptoms indicating a herniation at the L4 - L5 level; (A) marked hot zone in the midline with extension to the right; (B) same area at different brightness setting reveals maximum of temperature elevation to be of circular configuration and surrounded by lobulated processes of less increased surface temperature; (C) control thermogram 5 weeks later after conservative treatment and both subjective and objective improvement of the clinical signs shows retraction of increased heat pattern to a small, yet still hot circular which is easier distinguished after a different setting of brightness (D). Metal foil at interspace L4 - L5.

medullary tumor in the spinal canal were investigated by thermography; myelography preceeded thermography in 18 of these cases.

Of 4 ***neurinomas*** located in the cervical (1 case) and lumbar spinal canal (3 cases) the thermogram was unsuspicious in 3. In only 1 patient was there a hot circular area in the midline surrounded by a cool border zone but this was located 2 segments below the morphologic lesion (Fig. 11). All 3 ***meningeomas*** were located in the upper or middle third part of the thoracic spinal canal and had normal thermograms. Histology of 1 extradural lumbar tumor was not available and the thermographic pattern showed no abnormalities.

Four patients with ***gliomas*** distributed in the cervical, upper thoracic, lower thoracic and lumbar spinal cord all had normal back thermograms. One of 2 ***haemangiomas*** in the cervical cord and cervico-thoracic cord respectively was associated with a uniformly warm skin temperature of the cervical spine and dorsal neck region with an abrupt temperature niveau, i.e. decrease at the cervico-thoracic junction as occasionally seen in healthy individuals (Fig. 1).

An ***ependymoma*** in the medullary conus and a ***medulloblastoma*** in the upper cervical cord revealed normal thermal patterns as did 3 histologically ***undifferentiated tumors of*** various locations.

Syringomyelia

In 6 cases of syringomyelia, including those with a myelographically apparent marked widening of the spinal cord, no pathological alterations of the skin temperature at the level of the neurological defici; could be detected.

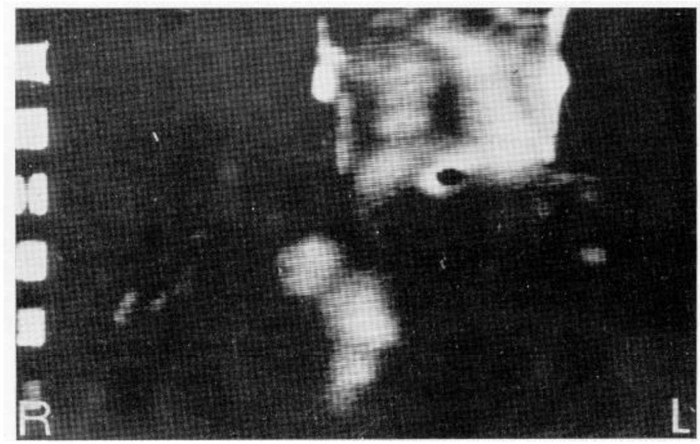

Fig. 9. Thermogram of neck and upper back in a male patient with acute disk herniation at C7 - Dl level. Hot circular spot overlying the spinous process of C7 (metal foil) with extension to the left and processes of elevated temperature covering most of the unilateral dorsal neck region.

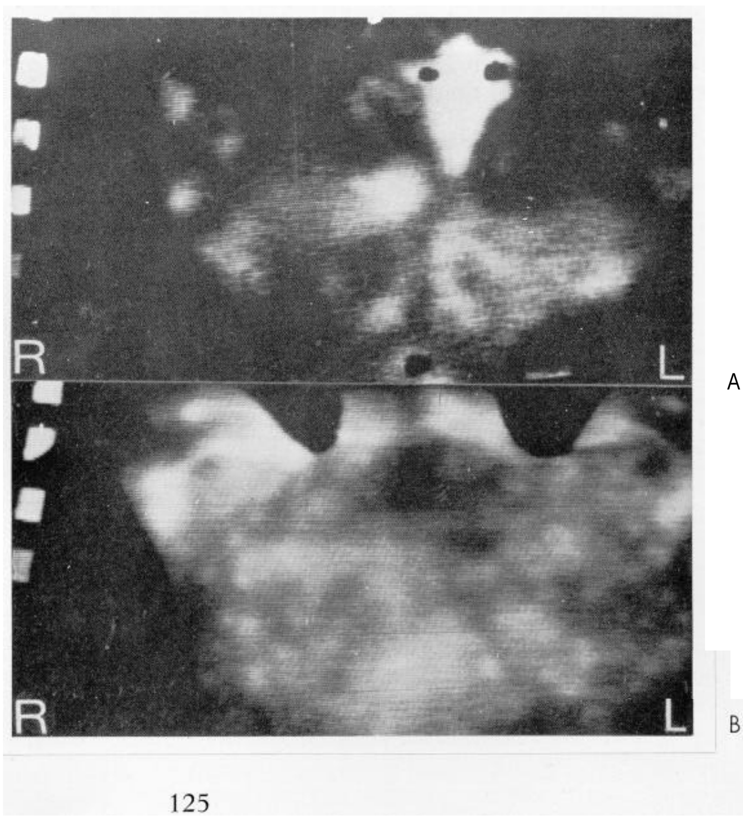

Fig. 10 A-B. Thermograms of neck and upper back in a 47-year-old male with a left-sided acute cervical disk herniation at the C7 level; (A) rhombus-shaped, well-demarcated hot area with enormous temperature increase, the axis running paravertebrally. The spinous process of C7 is marked as well as a point of maximal tenderness on pressure to the left; (B) control thermogram after several weeks of conservative treatment and relief of symptoms reveals a normal thermal pattern.

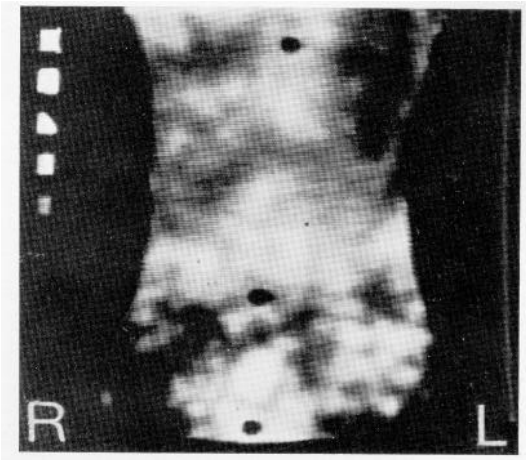

Fig. 11. Thermogram of the back in a 22.year-old woman with a neurinoma between L3 and L4. Circular hot spot with cool border zone in the midline sacral region, not corresponding to the level of involvement. Marked temperature differences between the buttocks. Three metal foils marking D4, L4 and upper portion of intergluteal cleft.

Metastases and haemangioma of vertebrae

Metastatic destruction or haemangioma of vertebral bodies proved not to be correlated with overlying skin temperature alterations. In 3 cases the lesion comprised 1 or 2 neighbouring segments of the lumbar spine and in 1 case the cervico-thoracic transition.

Traumatic lesions

Traumatic lesions investigated consisted of a complete spinal cord compression syndrome due to an old luxation fracture of a cervical vertebra (2 patients), of a recent lateral evulsion of the upper brachial plexus (1 patient) and of an old compression fracture of 2 upper thoracic vertebrae (1 patient). Thermography in these conditions proved unsatisfactory. There was neither a temperature niveau in cases of a transverse lesion nor were other localized or circumscribed pathological heat patterns obvious nor abnormal differences in symmetry apparent.

DISCLJSSION

The review of many thermograms as carried out in the first part of the study made it clear that a normal back thermogram does not exist. Even under the conditions of stable room temperature and the skin temperature adapted to it, the heat pattern of the back and spine varied considerably from patient to patient and in the same patient 23.

Normal body temperatures were determined before the era of thermography and special attention was drawn to the reproducibility on the one hand and to the deviations of skin temperature in symmetrical parts of the body on the other. Whilst it has long been known that the temperature of the extremities is subject to great variations and is not reproducible owing to the dependent vascular supply, this appeared not to hold for the trunk 7,8 22. Nevertheless symmetrical areas of the body surface, extremities or trunk, had revealed symmetrically distributed temperatures with the temperature differences usually not exceeding 0.5C, and exceptionally not more than 1.O°C [7, 18,20.] In the cases described here temperature deviations of up to 2°C between corresponding regions could be observed and a similar difference occurred in the same area when repeating a thermogram even after time intervals of less than 1 hour. The reason for the difference in findings could be the missing systematic mapping of the back which in earlier studies had been investigated at only very few points and by way of direct, i.e. contact thermometry.

Listing of the normal thermographic pattern of a back by the evaluation of many healthy individuals seems especially important since what one author considers normal ([16] his Fig. 13) is pathological for the other ([13] his Fig. 19), even though the findings from the lumbar region are almost identical. Furthermore the investigation of the normal back heat pattern has been almost restricted to the lumbar and sacral region, which is said to be almost warm [14, 16, 19] Edeiken et coB. (1968) described 4 areas with fairly constant features, namely the skin overlying the vertebral spinous processes, the intergluteal cleft and the sacro-iliac joints which are usually, but not necessarily, warm; the fourth area, the lumbo-sacral joint was usually relatively cold. But the numerical recording of our findings of the back, when subdivided into several regions, has shown that none of the areas investigated has constant temperature features and this is true for the spine as well as for the back. We find in contrast to the facial thermogram that the normal heat pattern has no constantly hypo- or hyperthermic region 17 and has warm circular areas especially along the spine, though previously the latter have been described as indicative of a disk protrusion 13.

A localized hyperthermic area may indicate the irritation of a nerve root subsequent to disk herniation. The frequency with which this abnormal finding is reported in lumbar disk herniations varies between 19% and 79% 10, 19 and seems to be dependent on the type of patient investigated and on the definition of what are normal findings. In the majority of healthy individuals, no hot spot overlies just one lumbar or cervical spinous process, though this has been found to occur occasionally. It could be argued that these normal hot spots represent silent disk herniations as observed by McRay (1966) during myelography of symptomatic lumbar disk herniations: here additional but asymptomatic cervical disk herniations were found which had never produced pain or other symptoms. But it seems unlikely that asymptomatic disk herniations give rise to pathological thermographic findings because, in the case of multiple herniations diagnosed by myelography, thermography did point to the one herniation causing the neurological deficit.

The results we obtained in cervical disk herniations were considerably better than those in lumbar herniations. This could be referred to the rare occurrence of a warm or hot midline stripe in the normal cervical region, in contrast to the lumbar region. The reason Heinz et ~011. (1964) had normal thermograms in all five cases of cervical or thoracic disk protrusions remains unexplained.

In our experience thermography for intraspinal tumors proved to be disappointing. If - as in rare instances - deviations from normal occurred they consisted of temperature elevations. The patterns were not markedly different from those of herniations or other conditions and therefore did not permit either a differential diagnosis or a statement concerning the type of tumor. While 1 of 4 neurinomas presented with an abnormal thermogram, possibly by way of a root compression, it was surprising that meningeomas or haemangiomas, with their abundant vascularization, did not. Heinz et ~011. (1964), who reported on 2 patients with neurofibromas, both with an abnormally increased heat pattern overlying the lesion, illustrated 1 case (their Fig. 7) which does not really show features differing from the normal. This is in contrast to their case of vascular malformation with a marked rhombus-shaped area of temperature elevation in the midline.

Bony metastases or a haemangioma restricted to the spinal vertebra did not give rise to overlying temperature increases, presumably due to their rather deep localisation. Once dorsal regions of the vertebrae, i.e. the spinous processes are destroyed the lesion is more likely to be detected by thermography. This is in contrast to peripheral bone tumors where thermography has proved able to distinguish between most of the malignant and benign tumors since elevations in temperature of the overlying skin are associated only with malignant processes 12. Farrel et ~011. (1971) described metastatic bone disease and found the lumbar spine to be a common site of involvement and one readily detectable by thermography. However, 10% of their findings were false - positives which suggests that the wide normal variations have not been taken sufficiently into account.

Spinal transverse lesions due to trauma or space-occupying lesions have been reported to almost constantly exhibit proximal temperature elevations and caudal temperature reductions at the level of the compression 15. Using a simple thermometer earlier investigators 6 had found temperature reductions only in the periphery of the extremities. In our material we could not find a thermal level in cases of a transverse lesion.

Old vertebral fractures have in our experience been thermographically silent. This seems reasonable since it is known from peripheral fractures that only when recent do they produce an increase in temperature. After the first week the temperature decreases slowly to a plateau and approaches normal over weeks to months 9.

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