Contact thermography of spinal root compression syndromes.

R Pochaczevsky and F Feldman

*AJNR Am J Neuroradiol* 1982, 3 (3) 243-250

http://www.ajnr.org/content/3/3/243

This information is current as of October 29, 2023.
Contact Thermography of Spinal Root Compression Syndromes

A thermographic technique is described that uses cholesteric liquid crystals that change color in response to variations in surface temperature. The crystals are embedded in elastic flexible sheets that conform to the contours of the torso and extremities. The technique is well suited to temperature measurement of individual skin dermatomes and myotomes. Typical heat patterns emanating from the torso and extremities have been observed and correlated with root compression syndromes at low cervical and low lumbosacral levels. The imaging results correlate well with clinical and surgical findings, particularly when the extremity dermatomes are included. The technique objectively documents the subjective complaint of pain and approaches myelography in accuracy. It was in agreement with myelography in 86% of cases and with surgery in 95% of cases. Liquid crystal thermography may, therefore, effectively screen patients for myelography and can complement it in identifying clinically significant abnormalities.

A noninterventional method, contact thermography, is described that uses cholesteric liquid crystals that undergo specific color changes in response to temperature changes. These properties have been used previously for contact color thermography [1–3]; we successfully used them in the detection of breast cancer [4, 5]. Elastic "Flexi-Therm" sheets (Flexi-Therm, Inc., Westbury, N.Y.) containing the thermally sensitive liquid crystals can be contoured to the extremities and torso by using a new device, an "air pillow" box (Flexi-Therm). Uniform skin contact with resultant consistently reliable thermograms have thereby been achieved. To date, spinal root compression syndromes have been conventionally diagnosed only by clinical means, electromyography, myelography, and, most recently, by computed tomography (CT). We found contact thermography valuable for screening and for identifying spinal nerve root compression.

Materials and Methods

Our material consists of 88 patients with clinical diagnosis of spinal root compression syndromes; 57 had myelograms and 37 were treated surgically. The apparatus (fig. 1A) consists of an hermetically sealed box, 37 × 38 × 3.5 cm, one side of which has a transparent plastic wall, while the other is composed of liquid crystals embedded in an elastomeric sheet. Air pumped into the box by a foot pump distends the sheet into a compliant convex surface (fig. 1B) suitable for contact thermography (fig. 1C).

Cholesteric liquid crystals have accurate and reliable color responses to specific temperature changes (table 1). The lowest temperature is displayed as a dark brown color and changes with progressive temperature elevation to tan, reddish brown, blue, and dark blue. Six or more air pillow boxes are available; they are numbered 26–35, corresponding to the median Celsius temperature ranges of their incorporated liquid crystal Flexi-Therm sheets. An instant camera with an electronic flash system and cross-polarized filter records color thermograms. A fixed-distance frame attached to the camera provides support for the air pillow and facilitates photography (fig. 1D).
TABLE 1: Typical Liquid Crystal Elastomeric Sheet Temperature Calibrations

<table>
<thead>
<tr>
<th>Color</th>
<th>Sheath (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>32</td>
</tr>
<tr>
<td>Dark brown</td>
<td>31.2</td>
</tr>
<tr>
<td>Tan</td>
<td>31.6</td>
</tr>
<tr>
<td>Reddish brown</td>
<td>31.9</td>
</tr>
<tr>
<td>Yellow</td>
<td>32.2</td>
</tr>
<tr>
<td>Green</td>
<td>32.4</td>
</tr>
<tr>
<td>Light blue</td>
<td>33.2</td>
</tr>
<tr>
<td>Dark blue</td>
<td>35.0</td>
</tr>
</tbody>
</table>

Note.—These calibrations permit determinations of temperature differentials (ΔT)° in comparable regions of the spine and extremities.

Technique

The examination is performed in a draft-free air-conditioned room with an approximate temperature of 20°C. The skin temperature of the back is stabilized by sponging with water and cooling for 10–15 min. A hair drier set on "cool" can further expedite skin drying and cooling. Sponging of the extremities is unnecessary. Patients should not smoke on the day of the examination since smoking may affect skin temperature [7].

The air pillow with the widest display for the patient's skin temperature is selected. A 30°C box is used initially. If brown colors seem to predominate, the skin temperature is too cold for that particular box since brown represents the lowest temperature on the liquid crystal color scale (table...
A 28°C box is then substituted. If blue colors predominate with the 30°C box, the skin temperature is too warm since blue represents the highest temperature on the liquid crystal color scale. If this happens, a 32°C box is used. The appropriate box is then firmly pressed against the patient's extremities. A colored image promptly appears on the liquid crystal sheet. The box is then slightly lifted from the skin surface to eliminate distortion and glare and the image is immediately photographed.

Routine views of the lumbosacral region and lower extremities consist of separate images of the lumbar region; buttocks; anterior, lateral, and posterior aspects of both thighs; anterior, lateral, and posterior aspects of both lower legs including the ankles; and the dorsal aspect of the feet, including the toes.

Routine images of the cervical spine and upper extremities include views of the posterior neck; both posterior shoulders; posterior, anterior, ulnar, and radial aspects of the forearms; and the dorsal and palmar aspects of the hands and fingers. Abnormal thermographic images should be repeated at least three times in succession to confirm their orientation to specific dermatomes and myotomes (figs. 2 and 3) [8].

A normal thermogram of the spine and extremities shows symmetrical heat emission, while root lesions have been
associated with temperature changes in the corresponding dermatomes and myotomes [6, 9–14]. The temperature changes may be related to reflex sympathetic vasoconstriction within affected extremity dermatomes and metabolic changes or muscular spasm in corresponding paraspinal myotomes. As a rule, temperature changes appear as zones of hypothermia in the affected extremity dermatomes [6, 9–14]. However, we found that hyperthermia occurs, particularly in the hands and feet. Both hypothermic and hyperthermic reactions are abnormal, since there should be no significant temperature difference between either side of the spine or between the extremities in normal individuals [15–20]. This was confirmed in our clinical experience, the exception being the occasional increase in temperature of the dominant arm and posterior forearm in very muscular males.

A normal thermogram of the spine (fig. 4) is characterized by a central zone of decreased heat emanation in the region of the spinal processes from the cervical spine down to the lower lumbosacral spine. The intergluteal fold is also recorded as hypothermic since it is not in contact with the liquid crystal sheets. The sacroiliac joints may show symmetrical localized increased heat emission [19, 20]. A positive or abnormal thermogram will show evidence of asymmetric increased heat production at myotomes in the lower lumbosacral region and asymmetric decreased heat production lateral to the midline along the cervical thoracic and upper lumbar spine.

Results

The findings in the 37 surgical cases are detailed in table 2. Contact thermography showed no false-negatives while myelography was equivocal or falsely negative in six patients, all of whom had surgical evidence of root compression. Three of these six had superior facet hypertrophy or lateral recess stenosis and three had hypertrophic spurs and/or herniated disks. There were two false-positives by contact thermography and no false-positives by myelography (table 3).

In eight operated cases in which contact thermography and myelography disagreed, thermography was fully correct in six cases and partly correct in one case. If only completely correct results were compared with surgical findings, the overall accuracy of contact thermography was 95% and that of myelography 84% (table 3).

Surgery was performed on only one of 12 patients with both a normal thermogram and myelogram. Although lateral spinal recess stenosis was found at the fifth lumbar level, there was no evidence of root compression at surgery. This case is considered a true-negative, although it may have conceivably caused intermittent root compression. Thermography was in agreement with myelography in 86% of 57 patients. Other correlations with myelography are shown in tables 3 and 4.

Discussion

Contact thermography appears to be particularly well suited for the diagnosis of root compression syndromes [6, 9]. Typical heat patterns have been observed in this study. S1 root involvement is associated with localized increased heat emission from the affected side of the lumbosacral region. The ipsilateral posterior thighs, and, in most cases, posterior and lateral aspects of the leg showed hypothermia while concomitant hyperthermia or hypothermia is seen along the lateral aspects of the foot and fifth toe. The inferomedial ipsilateral buttock may also show hypothermia (fig. 5).

L5 root involvement is usually characterized by hyperthermia in the corresponding side of the lumbar spine, usually radiating laterally; hypothermia of the ipsilateral midgluteal region, outer aspects of the thigh, and anterior leg; and hyperthermia or hypothermia of the dorsum of the foot and first through fourth toes (figs. 6 and 7).

C6 root compression syndromes are usually associated with hypothermia of the ipsilateral posterior cervical mus-

### TABLE 2: Root Compression Syndromes: Surgical Findings

<table>
<thead>
<tr>
<th>Causes, Locations of Root Compression</th>
<th>No. Patients (n = 37)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herniated disks, facet entrapment, osteophyte impingement, and/or spinal stenosis:</td>
<td></td>
</tr>
<tr>
<td>L5</td>
<td>25</td>
</tr>
<tr>
<td>S1</td>
<td>11</td>
</tr>
<tr>
<td>Spinal stenosis and facet entrapment, L4</td>
<td>3</td>
</tr>
<tr>
<td>Extraverted metastasis, S1</td>
<td>2</td>
</tr>
<tr>
<td>Neurofibroma:</td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>1</td>
</tr>
<tr>
<td>C6–T3</td>
<td>1</td>
</tr>
<tr>
<td>Ependymoma, L3</td>
<td>1</td>
</tr>
<tr>
<td>Syringomyelia, C3–C7</td>
<td>1</td>
</tr>
</tbody>
</table>

Note.—Some findings were at two or more levels.
Fig. 5.—Right S1 syndrome, 48-year-old woman with right leg pain due to surgically proven herniated L5–S1 disk. A, Gluteal regions. Decreased heat emission (darker brown) from right buttock and right inferomedial gluteal region (arrow) compared with left. B, Posterior thighs. Decreased heat emission (less green) from right thigh (arrow) compared with left. C and D, Lower legs, lateral views. Posterolateral aspect of right leg (C) is cooler (brown, arrow) than same region in left leg (D) (arrow). E, Myelogram. Right L5–S1 interspace defect (arrow) with amputation of S1 nerve root.

cles, posterior shoulder, radial side of the forearm, and a hot or cold thumb (fig. B). C7 root involvement is associated with hypothermia of the ipsilateral posterior cervical spine muscles, posterior shoulder, and dorsal aspect of the forearm. Hyperthermia or hypothermia of the ipsilateral second and third fingers is also seen in most cases. C8 root involvement is associated with hypothermia of the ipsilateral pos-

Fig. 6.—Right L5 root compression syndrome, 64-year-old woman with backache and pain in both lower extremities due to osteophytes and spinal stenosis (surgery). A and B, Lateral views of thighs. Decreased heat emission in right thigh (A) (reddish brown, arrow) compared with left (B), which shows increased heat emission (green, arrow). C and D, Anteromedial aspects of legs. Right leg (C) shows decreased heat emission (brown, arrow) compared with left leg (D), which shows increased temperature (green and blue, arrow). E, Dorsum of feet. Dorsum of right foot shows increased heat emission (blue and green, arrow) compared with left. F, Myelogram. Partial block at L4–L5 interspace (arrow).
Fig. 7.—Left L5 root syndrome, 49-year-old man with pain radiating to left leg. A, Lumbar area. Hot zone (green, upper arrow) and cold zone (brown, lower arrow) in left buttock. B and C, Lateral thighs. Left thigh (B) is cooler (less blue) than lateral right (C). D, Dorsum, first, second, and third toes (arrow) of left foot are warmer (blue) than right. (A and D reprinted from [6]).

Fig. 8. —Right C6 root compression syndrome, 64-year-old woman with burning sensation in both hands, especially right. A and B, Posterior shoulders. Right shoulder (A) is colder (brown, arrow) than left (B), which is warmer (green, arrow). C, Radial aspects of forearms. Right forearm (straight arrow) and thumb (curved arrow) are colder (less green) than left. D, Myelogram. Partial block at C5–C6 level due to large localized osteophytes.

terior cervical spine muscles, posterior shoulder, and ulnar aspects of the forearms. Hyperthermia or hypothermia of the ipsilateral fourth and fifth fingers is frequently noted.

We believe that thermographic accuracy in diagnosing spinal root compression syndromes is greatly improved when a simultaneous study of extremity dermatomes is cooler (less blue) than lateral right (C). D, Dorsum, first, second, and third toes (arrow) of left foot are warmer (blue) than right. (A and D reprinted from [6]).
included [6, 9–14]. This was documented in over one-third of our surgically proven positive cases where thermographic patterns in the lumbosacral region were either normal or inconclusive. A correct diagnosis was made, however, with definitely abnormal thermographic patterns in the extremities that adhered to known anatomic dermatome distributions (figs. 5 and 6).

The differential diagnosis of spinal root compression syndromes includes deep venous thrombosis [21], ischemic arterial disease [22], local trauma, and arthropathies of extremity joints [23]. These can be distinguished from spinal root compression syndromes in most cases by their distinct clinical pictures and by the failure of thermographic findings to be confined to a definite skin dermatome distribution. Varicose veins can be distinguished by their serpiginous course on the thermograms [21].

In the upper extremities, the differential diagnosis includes carpal tunnel syndrome with median nerve irritation and the ulnar nerve entrapment syndrome [24]. In median nerve involvement, there may be temperature changes in the thumb, second and third fingers, and radial side of the fourth finger. The ulnar nerve entrapment syndrome is usually associated with a cold dorsal forearm and temperature changes in the fourth and fifth fingers (Pochaczevsky R, unpublished data). In leprosy, hypothermic areas, as noted on thermography, are the sites of most marked sensory loss [25].

Root compression syndromes usually show hyperthermia in the lumbosacral and hypothermia in the cervicothoracic regions of the ipsilateral adjacent paraspinal myotomes. Musculoligamentous injuries of the spine and or osseous lesions without root compression appear to have thermographic changes localized to the spine [18]. They are not usually associated with thermographic changes in the extremities. Peripheral nerve trunk compression syndromes may cause hypothermia in their territorial distribution (fig. 9).

Simultaneous contact thermography and conventional infrared telethermography were performed on over 50 patients in a private practice setting. We could not include these patients here because our research was restricted to hospital patients. However, preliminary results indicate good correlation between these two thermographic techniques. Advantages of contact thermography over electronic infrared telethermography are low price, simplicity of apparatus, and high color contrast. The chief advantages of telethermography are that contact with the patient's skin is not required and larger body areas can be encompassed on each view.

Our preliminary results indicate that diagnostic accuracy of nerve root compression comparable to or better than by myelography (tables 2–4) may be achieved with contact thermography. This is true with the proviso that extremity dermatomes are included as part of the basic thermographic examination. Contact thermography is a noninvasive technique that appears to have high sensitivity and correlates well with clinical and surgical findings. In our clinical experience, negative thermograms were always associated with negative myelograms and a benign clinical course (table 4). There were no false-negative thermograms in the surgically treated cases (table 3). Thermography may, therefore, effectively serve to screen patients for myelography and can complement myelography in identifying clinically significant abnormalities. In another reported series of 130 patients, thermography of the spine and extremities was 93% accurate as compared with physical findings, while electromyography was only 82% accurate [14].

Our clinical experience shows that contact thermography can objectively document the subjective complaint of pain. Demonstrable alterations in surface temperature corresponding to the distribution of pain or specific root dermatomes strongly suggest that a somatic abnormality exists despite other normal examinations including myelography.

ACKNOWLEDGMENT

We thank Seymour Katz for technical assistance.

REFERENCES