Background—The aim of the study was to assess the consequences of severe spinothalamic tract lesions resulting from lateral medullary infarct and to show that a specific pain perception can be elicited by strong thermal stimulation.

Case Descriptions—Both patients examined presented with severe thermoalgic dissociation of the limbs contralateral to the lesion, with normal discriminative somatosensory perception and motor strength. They reported pain perception when touching very warm (>50°C to 60°C) objects and a brisk, occasionally uncontrolled withdrawal reaction of the arm and hand under the same conditions, without any perception of the heat nature of the stimulus. Warm stimulation, <45°C, elicited no thermal perception or discrimination. Pain perception could be elicited in both patients by increasing the temperature, with a reproducible threshold of 47°C to 49°C. Pain always occurred after a prolonged delay of 8 to 10 seconds in response to threshold heat, and was described as deep and osseous, and clearly different from that perceived on the nonaffected side. The delay was much shorter when the temperature was increased by 4°C to 5°C. Cold stimulation elicited similar pain perception in one patient. Analysis of subjective perception of laser stimulation showed a much higher pain threshold on the affected hand. There were no laser-evoked potentials on this side, which suggested major spinothalamic injury. Assessment of the RIII noxious reflex revealed persistent response withdrawal reactions, with an increased threshold on the affected side, and partial consciousness of the noxious nature of the stimulus.

Conclusions—To our knowledge, this is the first description of the appearance of pain perception of high temperatures in patients with severe spinothalamic injury who are suffering from a complete loss of temperature perception. This implies that noxious thermal stimulation can still be perceived via extra spinothalamic pathways (which are slow and multisynaptic), such as the spinoreticulothalamic tract. Patients with Wallenberg syndrome should be informed and made aware of their residual perception of and reactions to noxious stimulation. (Stroke. 1999;30:2223-2229.)

Key Words: cerebral infarction ■ medulla ■ pain ■ spinothalamic tracts
rotary vertigo, and loss of balance. Neurological examination revealed right-sided ataxia, Horner’s syndrome, diplopia with skew-deviation, and severe left-sided thermal and pain analgesia on the limbs and trunk, with relative sensitivity of the face. Lingual and pharyngeal examination was normal, as were his motor strength and discriminative sensitivities (light touch, 2-point discrimination, monofilament perception, position sense, pallesthesia). MRI (T2 sequences) revealed a right-sided lateral medullary hyperintensity (Figure 1). The right vertebral artery was not opacified on humeral angiography; its distal part (with the posteroinferior cerebellar artery) was supplied by the left vertebral artery.

He recovered from the gait disorder relatively rapidly and had regained full autonomy in daily life when discharged from the rehabilitation center (Barthel Index: 100/100). Follow-up examinations (1993 to 1998) revealed persistent, complete left-sided anesthesia for painful and thermal stimuli, and diplopia in his right gape. In the first few months after discharge, the patient described particular reactivity to thermal stimuli. His left upper limb underwent a brisk withdrawal reaction when touching warm objects on several occasions, without any consciousness of the temperature. Burning never occurred. The patient later learned to control and inhibit this reaction when approaching warm objects. Furthermore, he once had a severe knife cut on a finger without experiencing any pain and without any withdrawal reaction. This led us to carry out a more complete investigation of his heat and pain perception.

**Patient 2**

A 60-year-old man, without any neurological history, presented in 1998 with intense rotary vertigo, loss of balance, left facial paresthesia, and a sensation of “warmness” on his right side. Examination showed severe left static and kinetic ataxia, multimodal anesthesia of the left face and tongue, left velar and pharyngeal paresis, Horner’s syndrome, and oblique diplopia. He also suffered from severe thermal and pain anesthesia on the right side, which did not involve his facial and upper cervical areas. Muscle strength was normal. Superficial and deep somatosensory perceptions were slightly reduced on the left leg, but this disorder rapidly disappeared. MRI (T2 sequences) showed a left posterolateral medullary hyperintensity (Figure 2). Angiographic MRI revealed no flow in the left vertebral artery.

The patient slowly recovered his sense of balance and recovered from the swallowing disorder. During the rehabilitation stay, he occasionally had brisk withdrawal reactions of the right arm when touching warm objects (such as a coffee cup). As in the case of patient 1, he learned to control these reactions when approaching warm objects. He also noticed that prolonged contact with warm objects caused deep pain in his fingertips. This feeling was clearly different from any previous experience of pain and from what was perceived on the contralateral side. This pain was described as deep, osseous, and articular. After discharge from the rehabilitation unit, he was severely burned by oil on the right hand while cooking. He perceived pain immediately, but the perception rapidly disappeared, which contrasted with the persistence of severe cutaneous traces for a few weeks.

**Evaluation of Sensory Disorders**

These evaluations were performed at 6 months for patient 1, with a follow-up 5 years later, and at 1 month in patient 2, with a follow-up at 4 months. Both patients gave their informed consent to participate in the study.

**Superficial and Deep Discriminative Sensibilities**

Superficial and deep sensibilities were assessed using light touch (from 0 [no tactile perception] to 4 [perception of light
Upper Limb Examination in Both Patients

<table>
<thead>
<tr>
<th>Discriminative sensitivities</th>
<th>Patient 1</th>
<th>Patient 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light touch (thumb + hand) (0–8)</td>
<td>8 8</td>
<td>8 8</td>
</tr>
<tr>
<td>Monofilament J 4.31 (fingers extremity) (0–5)</td>
<td>5 5</td>
<td>5 5</td>
</tr>
<tr>
<td>Monofilament F 3.61 (fingers extremity) (0–5)</td>
<td>4 4</td>
<td>3 3</td>
</tr>
<tr>
<td>Position sense (thumb + wrist) (0–8)</td>
<td>8 8</td>
<td>8 8</td>
</tr>
<tr>
<td>Discrimination of thermal stimuli (0–45°C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discrimination 0–40°C (hands, 0–5)</td>
<td>2 5</td>
<td>3 5</td>
</tr>
<tr>
<td>Perception and reactions to heat (&gt;45°C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threshold of pain occurrence, °C</td>
<td>47 44–45</td>
<td>48 44–45</td>
</tr>
<tr>
<td>Delay of pain occurrence, s</td>
<td>8–10 1–2</td>
<td>6–7 1–2</td>
</tr>
<tr>
<td>Perception and reactions to cold (&lt;0°C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay of pain occurrence (hand in ice), s</td>
<td>15 8–10</td>
<td>18 7–8</td>
</tr>
<tr>
<td>Perception of pinpricks and hair pulling (presence of pain, 0–5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repeated pinpricks</td>
<td>0 5</td>
<td>0 5</td>
</tr>
<tr>
<td>Repeated hair pulling</td>
<td>0 5</td>
<td>0 5</td>
</tr>
<tr>
<td>Subjective perception of laser stimulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threshold of pain (stimulus intensity), mJ</td>
<td>468 311</td>
<td>838 474</td>
</tr>
<tr>
<td>Somatosensory evoked potentials (MNS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latency of N20, ms (N &lt;23.4)</td>
<td>20.8 19.9</td>
<td>21.3 20.7</td>
</tr>
<tr>
<td>Laser-evoked potentials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latency of N1, ms</td>
<td>194</td>
<td>304</td>
</tr>
<tr>
<td>RII reflex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper limb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RII threshold (stimulus intensity), mA</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>RII latency, ms</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Lower limb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RII threshold (stimulus intensity), mA</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>RII latency, ms</td>
<td>84</td>
<td>93</td>
</tr>
</tbody>
</table>

Perception of and Reactivity to Thermal Stimuli

Subjective Perception and Discrimination of Thermal Stimuli (0°C to 45°C)
The patients’ hands were placed in water at temperatures of 0°C to 45°C. Patient 1 had no subjective perception of temperature on his affected hand, and was unable to discriminate between 2 temperatures (0°C and 15°C; 0°C and 30°C; 0°C and 40°C; repeated forced-choice recognition), whereas this ability was perfectly preserved on his nonaffected hand. Patient 2 reported uniform perception of “lukewarmness” on his affected hand, whatever the temperature, but his subjective perception was normal on the nonaffected side. He was also unable to discriminate between temperatures.

Perception of and Reactivity to Heat (>45°C)
The patients’ hands were placed briefly in hot water (45°C to 55°C). We measured the time (in seconds) to the appearance of subjective perception and the intensity of perception (from 0 [no pain] to 100% [unbearable pain]). Patient 1 reported distal pain, deep and osseous, in his affected hand, with a threshold of 47°C and with an 8- to 10-second delay. This delay was much shorter at higher temperatures (at 50°C, 3 seconds; at 55°C, 1 to 2 seconds), but the response was never immediate. Pain persisted for 2 to 3 seconds after withdrawal.
of stimulation. He felt no sensation from prolonged immersion (up to 15 seconds) in water at 45°C or 46°C. Pain perception had a lower threshold (44°C) and was more rapid on his nonaffected hand. These results for the first (6 months) and follow-up (5 years) examinations were very similar.

Patient 2 had a very similar pattern of perception. The delay was 8 to 10 seconds at the threshold temperature (49°C), and the subjective intensity was 40/100. The delay was shorter at higher temperatures (at 50°C, 4 seconds; at 55°C, 1 to 2 seconds), and the intensity increased with prolonged exposure (eg, at 51°C: 40/100 at 4 seconds and 70/100 at 8 seconds).

The onset of pain was associated with a controllable need for hand withdrawal in both patients. Reactions to higher temperatures were not assessed. The exposure to the 55°C stimulation was always brief (<2 to 3 seconds). No patient had any persistent pain or cutaneous lesion resulting from the stimulations.

**Subjective Perception and Reactions to Cold (<0°C)**

We investigated the patients' reactions to cold stimuli by placing an ice cube in the hand for 30 seconds, placing the hand in a container filled with ice cubes for 30 seconds, and by slowly moving ice over the skin of the limbs and trunk to test for allodynia. Patient 1 had no subjective sensation of cold or pain when an ice cube was placed in his affected hand. Placing the hand in ice elicited a moderate pain reaction (25/100) of the fingers and hand after 15 seconds, which intensified somewhat after 20 seconds (40/100). Cold perception by the right hand was immediate, and a pain reaction occurred after 8 to 10 seconds. The subjective quality of the pain on the 2 sides was clearly different. The pain on the affected side was described as deep, osseous, and identical to that perceived using warm stimulation (>47°C). Cold stimulation never elicited allodynia. Patient 2 had no subjective sensation of cold or pain in any condition on his affected side, whereas his reactions on the nonaffected side were normal.

**Perception and Reactivity to Pain**

**Subjective Perception of and Reactions to Pinpricks, Hair-Pulling, or Mechanical Stimulation**

On repeated stimulation, neither patient had any pain sensation in his affected arm or leg (case 1, left side; case 2, right side) or his trunk, with a clear-cut vertical limit. Pain perception, however, was perfectly preserved on the contralateral side. Strong mechanical stimulation applied to the fingers or hand did not elicit pain.

**Subjective Perception of and Reactions to Laser Stimulation**

The subjective thresholds of pain were evaluated using brief (1 millisecond) thulium laser stimulation of the dorsum of the hand, following the Treede procedure and using a skin area 5 mm in diameter, with each stimulus in a different place; the intensity was gradually increased then decreased (5 times). Patient 1 had a higher threshold value on his affected side (mean±SD 468±48 mJ) than on his nonaffected side (mean±SD 311±60 mJ) or control values (mean±SD 319±65 mJ). Similar results were obtained with patient 2, with an increased threshold on the affected side (mean±SD 838±71 mJ), in comparison with the nonaffected side (mean±SD 474±54 mJ).

**Electrophysiological Investigations**

The following investigations were performed to assess the function of the main somatosensory pathways.

**Somatosensory Evoked Potentials**

The median nerve was stimulated at the wrist level by electrical square-wave pulses (0.1 ms duration; 5.1 Hz). Stimulus intensity was adjusted to produce a minimal thumb movement. Recording was performed with use of active electrodes: they were placed at the Erb's point, at the cervical level, and at the parietal scalp area (C3 and C4, 2 cm behind C3 and C4, as defined by the Internation 10–20 System), with an ipsilateral or contralateral earlobe reference electrode. Two series of 500 to 1000 acquisitions were necessary to ensure the reproducibility of the waveform. In both patients, parietal potentials (N20) were of normal and symmetric latencies and amplitudes (Figure 3).

**Laser Evoked Potentials**

The dorsum of the hand was warmed with a thulium laser, with a stimulus length of 1 ms; each stimulus in a different place; 2 series of 20 stimuli each; 8- to 12-second intervals; and intensity of 2× the subjective nociceptive threshold for the “normal” side, without exceeding 700 mJ (600 mJ in the first patient and 700 mJ in the second). Recording electrodes were placed over Cz, reference to linked earlobes. The patients' evoked potentials were compared with those obtained in 15 normal adults, ranging in age from 20 to 62 years (mean 33 years). No potential was recorded for either patient when the affected side was stimulated (Figure 4). When the preserved side was stimulated, the latency of the negative potential (N1) was 194 ms in patient 1 and 304 ms in patient 2 (control values [mean±SD] 199±18), and the latency of the main positive potential (P2) of 432 ms in patient 2 (control values 325±37). This late potential was difficult to evaluate in patient 1, because the amplitude was severely reduced; he suffered from marked hyperhidrosis on the left side of the scalp and trunk, which could have contributed to the reduction in amplitude when the preserved right hand was stimulated. The amplitude of both potentials (N1 and P2) was normal in patient 2.

**The RIII Noxious Reflex**

This study evaluated withdrawal reactions to electrical stimulations. The patient lay comfortably in a reclining armchair. Each upper limb was stimulated using electrical stimulation by trains (8 pulses at 400 Hz, 0.1-ms duration) of the ulnar nerve at the wrist (Viking LE, Nicolet). Responses were recorded from surface electrodes placed over the wrist flexors (flexor carpi radialis). Stimulus intensity ranged from 0.1 mA to 30 mA. In the second patient, lower limbs were assessed similarly (sural stimulation at the ankle; biceps femoris recording). On the upper limbs, both patients had a higher response threshold (intensity evoking the RIII reflex with a probability of 80% to 90%) on the affected side than on the nonaffected side. Patient 2 had similar results in the lower limbs (Figure 5). Both patients experienced pain on the
nonaffected side, but the stimulation applied to the affected side elicited disagreeable perception rather than pain.

Discussion

We found that a specific type of pain could be elicited by thermal (hot or cold) stimulation of patients with a major spinothalamic injury without evidence of lesion of the lemniscal pathway, once a specific threshold was exceeded. Thermal and electrical stimulation of the affected side elicited withdrawal reactions. Noxious mechanical stimulation was not clearly associated with a sensation of pain and avoidance reaction.

The consequences of severe spinothalamic injury have been investigated in patients presenting with spinal cord lesion. In 2 cases of unilateral injury of the lateral column, Wall and Nordenbos reported complete insensibility to cold and warm tubes of water on the contralateral side. After bilateral infarction of the anterior two thirds of the cord, Nathan et al described lost sensation of all painful and thermal stimuli caudal to the lesion (T12). Pinprick was felt as touch. Light touch (cotton, von Frey hairs), 2-point discrimination, and position sense were remarkably preserved, as was graphesthesia. In other patients with unilateral or bilateral anterolateral cordotomy for treating pain due to malignant disease, the sense of movement, knowledge of position, and light touch were similarly preserved. The spontaneous perception of pain was usually reduced in association with reduction in pinprick perception, but pinprick anesthesia was often incomplete. In some descriptions, the greatest deficits were reported to be in the sensation of skinfold pinch and skin cooling. However, in any patient, the perception of relatively high temperature was not assessed.

A lateral medullary infarct is a useful model for investigating the consequences of a selective and severe lesion of the spinothalamic tract. The severity of the spinothalamic injury in both of our patients was clearly confirmed by the

Figure 3. Somatosensory evoked potentials in patient 2, who presented with a left lateral infarct without impairment of discriminative sensitivities. Potentials are normal on both sides (C’, C’4), with right (R) or left (L) median nerve stimulation.

Figure 4. Laser evoked potentials in patient 2, who presented with a right anesthesia for pain and heat. There is an absence of any potential when stimulating the right affected side (R) in comparison with the left preserved side (L), which confirms the severe injury of the spinothalamic pathway (intensity of stimulations 700 mJ).
lasting lack of laser-evoked potentials on the side contralateral to the lesion. The degree to which sensitivity to pain is recovered in these cases is reflected by the normalization of the laser evoked potentials. The delayed laser evoked potentials obtained by stimulating the preserved side in the second patient could be explained by the patient’s age, which was relatively higher than that of controls. These patients can also be used to study the subjective perception of pain and the spinal reflex response to noxious heat and painful stimuli in the absence of the spinthalamic tract.

The main finding in both cases of this study was that thermal stimulation did not evoke a sensation of heat or cold but was able to produce pain. This was especially evident with use of warm stimulation above a specific and reproducible threshold of 47°C to 49°C. The temperature threshold was higher than the normal threshold to noxious phenomena, which is near 45°C. The patients did not experience heat, but the pain occurred when the temperature exceeded a specific, reproducible threshold of 47°C to 49°C. The delay before perception was relatively long, but it decreased considerably at higher temperatures. The experience of pain was also clearly different from that on the preserved side: pain sensation was not superficial, but was instead deep and osseous or articular. Furthermore, no pain could be elicited in these patients using pinprick, hair-pulling, and strong mechanical stimulation. In both cases, the dissociation between the preservation of discriminative sensitivities and the alteration of heat and pain perception was more severe and relatively different from what has been described by Casey et al in patients with cortical, thalamic, or brain stem lesions.

This raises the question of the mechanism underlying this perception. Assuming that the function of the spinthalamic tract ipsilateral to the lesion is severely altered, there are 3 hypotheses. The first is that perception is conveyed by the spinoreticulothalamic pathway. This tract, due to its internal location, can be relatively preserved in Wallenberg syndrome. It has projections to the medulla,pons, mesencephalon, and internal thalamus. Its electrical stimulation has no definite consequence in patients with nociceptive pain. In the case of deafferentation pain, stimulation is able to elicit contralateral burning and pain perception (denervation hypersensitivity). This preservation could explain inferior limb allodynia in the second patient. On the hand of the affected side, the perception of pain was relatively different. No patient reported hyperesthesia or burning sensation, which are 2 main components of the classical allodynic syndrome. The perception was relatively diffuse and deep, however, which could correspond to what we know about the spinoreticulothalamic tract. A second hypothesis is that pain is mediated by the spino-pontoamygdalar pathway, which has been described in animals. However, in humans, activation of the amygdala was not observed in allodynia elicited by subcutaneous capsaicin injection in normal subjects or by cold stimulation in Wallenberg syndrome. The third hypothesis would be that the way to the cortex is contralateral to the infarct and ipsilateral to the affected hemibody. In this alternative, there are at least 3 possible candidates: the ipsilateral spinothalamic, spinoreticulothalamic, and spinopontoamygdalar tracts. Bilateral projections of these systems exist in animals. The lemniscal system may also be involved, because it may take part in visceral nociceptive perception; however, there is no evidence that this pathway plays a role in cutaneous pain. The information processing to the cortex is slow and multisynaptic, as indicated by the delay between the stimulation application and the occurrence of painful sensation.

Patients can still present with motor withdrawal reactions to noxious stimulation, and principally to warm stimulation. The reaction threshold is difficult to evaluate for thermal stimulation. Our clinical observation suggests that, in the first few weeks or months following a stroke, when patients had no experience with their new condition resulting from the spinothalamic tract lesion, avoidance reactions could occur without control. The withdrawal movement was unexpected and could prevent the patient from picking up warm objects. However, the reflex movement could be inhibited later, at least if the noxious character of the stimulus was relatively limited, as when holding a coffee cup. Thus, warm objects could be manipulated without any great problem.

Electrical stimulation gives a more precise evaluation of the reflex response to noxious stimuli. The threshold on the affected side was higher than the threshold on the normal side, as described by other authors. Garcia-Larrea et al found that in patients with cervicothoracic anterolateral cordotomy, the contralateral RIII reflex was always dissociated from subjective pain, eg, present in the absence of pain perception. Our patients reported disagreeable perception and discrete pain on the affected side. This suggests that pain can also be elicited by nonthermal stimuli. The persistence of
avoidance reactions in such patients is clearly explained by the spinal location of the reflex loop. Roby-Brami et al.33 showed that the RII nociceptive reflex is still present in tetraplegic patients suffering from a complete spinal cord transection at the cervical level and that the mean threshold is similar to that of normal subjects.

The increased threshold on the side contralateral to the lesion in patients with spinothalamic injury suggests the lesion of facilitator systems arising from higher structures located in the brain stem or hemisphere, or the relative release and facilitation of inhibitory systems,8,34 or both. The first includes spinoreticular fibers to the medial reticular nuclei gigantocellularis and magnocellularis.35 A lesion of this system could explain the increased threshold in Wallenberg patients.8 The second includes the antinociceptive structures of the brain stem.11,32,36

In conclusion, patients with Wallenberg syndrome and severe spinothalamic lesions are still able to perceive pain and retain avoidance reactions to some forms of stimulation, mostly thermal. This helps to explain the relative protection from most aggressive stimulations encountered in daily life. Patients admitted for neurological evaluation or rehabilitation must be informed and made aware of their residual perceptions and of possible uncontrolled reflex responses to noxious stimuli.

References
Analysis of the Perception of and Reactivity to Pain and Heat in Patients With Wallenberg Syndrome and Severe Spinothalamic Tract Dysfunction
M. Rousseaux, F. Cassim, B. Bayle and E. Laureau

Stroke. 1999;30:2223-2229
doi: 10.1161/01.STR.30.10.2223
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1999 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/30/10/2223

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/