Thalamic stimulation for neuropathic pain

IAN M. TURNBULL, M.D., RALPH SHULMAN, M.D., AND W. BARRIE WOODHURST, M.D.

Division of Neurosurgery, Departments of Surgery and Psychiatry, University of British Columbia and Vancouver General Hospital, Vancouver, British Columbia, Canada

Eighteen patients with neuropathic pain underwent thalamic electrode implantation. Satisfactory initial pain relief ensued in 14, and their electrode systems were internalized for long-term use. Twelve of the 14 continue to obtain either complete or partial pain relief by regular stimulation. One of the other two patients has had a complete remission of pain, apparently spontaneously, and the other had to have the electrode removed after it retracted from his thalamus on two occasions. The electrodes have been placed in the sensory nucleus of the thalamus where stimulation evokes paresthesias in the painful part of the body. Technical problems consisting of our inability to locate the target in two patients and our failure to fix the electrode adequately in one prevented us from employing the treatment in three patients. The fourth patient had temperature dysesthesia which was not altered during 2 weeks of stimulation.

KEY WORDS • pain • brain stimulation • causalgia • arachnoiditis • brachial plexus injury • thalamus

Sensory pathway injury may cause chronic pain. One may distinguish between pain caused by an active disease, such as sarcoma of the thigh, and pain resulting from nerve damage on the basis that pain due to noxious stimulation can usually be relieved for months or years by transection of a sensory pathway central to the lesion, while pain caused by partial or complete deafferentation, here called "neuropathic pain" so as to include the pain of perineural fibrosis, seldom responds to such a surgical approach.

An electrode in the thalamic sensory relay nucleus can activate tertiary neurons to produce a tingling sensation that feels as if it originated in the denervated part of the body. The hypothesis that stimulation of thalamic neurons deprived of their normal peripheral connections would suppress denervation pain was tested clinically by Hosobuchi, et al.,1 in anesthesia dolorosa from trigeminal nerve damage, and by Mazars, et al.,9 in a variety of neuropathic pains. The work to be reported in this paper was stimulated by these encouraging studies and by the lack of satisfactory alternative treatment.

Clinical Material and Methods

Patient Population

Criteria for patient selection remained consistent throughout the series. All had pain for at least 2 years, and were unable to participate in work or leisure activities. The pain was caused by injury to sensory pathways or fibrosis around nerve roots. The patients were referred by specialists after conventional surgical and medical treatment had failed. They were assessed psychiatrically before and after treatment. Although depressed and desperate, all had histories of coping well with life before the pain began. None appeared to be deriving much social or monetary gain from being disabled. They proceeded with the operations after being advised of possible risks and that the treatment might not be effective. Eighteen patients had electrodes* implanted, and 14 had the electrodes linked to subcutaneous receivers at second operations. The electrodes were removed from the other four.

Implantation Technique

A parasagittal, coronal burr hole is drilled under local anesthesia with the patient in a Todd-Wells stereotaxic apparatus.† After ventriculography, the patient is positioned to allow a monopolar stimulating electrode, 1.4 mm in diameter with a 1-mm ex-
posed tip, to pass through the nucleus ventrocaudalis (nucleus ventralis posterior, principal sensory relay nucleus). The Van Buren-Borke atlas and the maps of Emmers and Tasker are used for guidance. Stimulation at 2-mm steps is undertaken, beginning 10 mm above the intercommissural line and continuing 6 mm beyond. This trial is continued until a site is found where low-voltage stimulation refers paresthesias to the painful part of the body. Usually such a site is detected during the first and only passage of the electrode.

A flexible electrode with four contact areas spaced over the most distal 10 mm is inserted into the thalamus. At first a handmade inserter was used, but now the Trent Wells inserter is employed. Difficulties we experienced fixing the electrode to the burr hole with acrylic or suture have been overcome by using the Richardson burr hole cap that is now available. The electrode is connected to a temporary extension which is brought out through the scalp.

During the ensuing week or longer, the patient activates the electrode between various combinations of the four contact areas. If stimulation relieves the pain, the pair of contacts that achieve this at lowest voltage is identified for permanent use. A flexible cable is implanted under general anesthesia to connect the chosen pair of contacts with a subcutaneous receiver in the subclavicular region. Subsequent stimulation is achieved from a battery-operated stimulator coupled to the receiver by way of a disc-shaped antenna held to the skin over the receiver.

Relief of Pain

Pain relief was judged to be complete if the patient so claimed, and if he discontinued analgesics and resumed all previously abandoned activities. Pain relief was thought to be partial when it was not completely controllable by stimulation but was sufficiently improved that the patient could reduce analgesic intake and increase his activities. All those regarded as obtaining pain relief from stimulation have used the stimulator regularly since implantation and experience a return of pain if the stimulator is not used.

Sensory examinations were undertaken before, during, and after stimulation. Relative sharpness of the pinprick was compared between the side of the body being stimulated and the other side. Light touch appreciation was assessed with cotton wool.

Case Reports

Stimulation by the temporary extension through the scalp relieved pain in 14 patients and the systems were internalized at a second operation. Two of these patients underwent the procedure a second time to obtain bilateral electrodes. In four, the electrode did not function adequately and was removed.

System Internalized

The results in the 14 patients who had the systems internalized are summarized in Table 1 and below.

Case 1. Two years earlier, this 36-year-old woman sustained a head injury that resulted in burning pain of the left side of the face and leg. The concurrence of diplopia and ptosis indicated midbrain damage of sensory and oculomotor pathways. Since thalamic stimulator implantation in June, 1975, she has suppressed the pain with stimulation of 10 minutes' duration once or twice a day. She has resumed her work as a bank teller and continues to use the stimulator.

Case 2. This 41-year-old longshoreman had undergone six operations on his lumbar spine between 1967 and 1973, but chronic burning pain in the left buttock and leg persisted. An electrode was implanted in June, 1975. He found that stimulation relieved the pain, and he used it intermittently throughout the day. Fourteen months after implantation, he tripped at work, striking his head hard enough to become unconscious briefly. Subsequently, the stimulator did not function, and skull films revealed that the electrode had retracted from the thalamus. In November, 1976, the electrode was replaced, and once again stimulation stopped pain.

Two months after the reimplantation, the stimulator failed to cause paresthesias in the leg, and began to cause motor responses in the arms and face at high-power settings. X-ray films revealed that the electrode had once again withdrawn from the thalamus. The electrode was damaged during an attempt to reimplant it and was removed. A few hours after this third implantation attempt, he had two convulsions.

Eighteen months after the final operation he had a slight sensory deficit in the left arm. He remained free of seizures, but his chronic left leg pain was as bad as ever. He looked back on his year's experience with the thalamic stimulator as a happy interval.

Case 3. This 37-year-old accountant had undergone a lumbar discectomy in 1962 for pain in the right leg, and was well for 10 years. The pain recurred, and three laminectomies between 1972 and 1974 gave transient pain relief. The fifth decompression in January, 1975, was followed by persistent right leg pain with tingling in the calf. He began to develop a dependency on narcotics.

A thalamic electrode was implanted in September, 1975. The electrode was positioned more medially than intended. Two weeks after leaving the hospital, he found that paresthesias induced by stimulation were stronger in the right arm than the leg, and became less effective for suppressing pain. The ele-
Clinical data in 14 patients with internalized systems

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs.), Sex</th>
<th>Diagnosis</th>
<th>Stimulation Site† (mm)</th>
<th>Duration of Stimulation (mos)</th>
<th>Pain Relief</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36, F</td>
<td>midbrain injury</td>
<td>14 rt 3 above 4 ant</td>
<td>47</td>
<td>complete</td>
</tr>
<tr>
<td>2</td>
<td>41, M</td>
<td>lumbar arachnoiditis</td>
<td>19 rt 5 above 5 ant</td>
<td>14</td>
<td>complete</td>
</tr>
<tr>
<td>3</td>
<td>37, M</td>
<td>lumbar arachnoiditis</td>
<td>12 lt 2 below 3 ant</td>
<td>1</td>
<td>transient</td>
</tr>
<tr>
<td>6</td>
<td>34, F</td>
<td>lumbar arachnoiditis</td>
<td>17 lt 1 above 6 ant</td>
<td>1</td>
<td>complete</td>
</tr>
<tr>
<td>8</td>
<td>61, M</td>
<td>leg amputation stump pain</td>
<td>17 rt 6 above 3 ant</td>
<td>16</td>
<td>partial</td>
</tr>
<tr>
<td>9</td>
<td>37, F</td>
<td>lumbar arachnoiditis</td>
<td>16 rt 2 below 2 ant</td>
<td>13</td>
<td>complete</td>
</tr>
<tr>
<td>11</td>
<td>70, M</td>
<td>sacral plexus causalgia</td>
<td>13 rt 1 below 1 post</td>
<td>12</td>
<td>complete</td>
</tr>
<tr>
<td>12</td>
<td>54, F</td>
<td>lumbar arachnoiditis</td>
<td>15 lt 2 below 3 ant</td>
<td>11</td>
<td>partial</td>
</tr>
<tr>
<td>13</td>
<td>42, M</td>
<td>median nerve causalgia</td>
<td>14 rt 1 above 3 ant</td>
<td>11</td>
<td>partial</td>
</tr>
<tr>
<td>14</td>
<td>51, M</td>
<td>brachial plexus avulsion</td>
<td>13 lt 2 above 2 ant</td>
<td>6</td>
<td>partial</td>
</tr>
<tr>
<td>15</td>
<td>58, M</td>
<td>lumbar arachnoiditis</td>
<td>15 lt 1 above 3 ant</td>
<td>5</td>
<td>partial</td>
</tr>
<tr>
<td>16</td>
<td>34, M</td>
<td>lumbar arachnoiditis</td>
<td>16 rt 3 below 1 ant</td>
<td>4</td>
<td>complete</td>
</tr>
<tr>
<td>17</td>
<td>62, M</td>
<td>lumbar arachnoiditis</td>
<td>14 rt 1 below 2 ant</td>
<td>2</td>
<td>complete</td>
</tr>
<tr>
<td>18</td>
<td>38, M</td>
<td>supraborbital causalgia</td>
<td>12 rt 2 below 6 ant</td>
<td>1</td>
<td>complete</td>
</tr>
</tbody>
</table>

*Eighteen electrodes in 14 patients (two patients have bilateral electrodes, two had an electrode replaced in a different site).

*Location is given as a point midway between the pair of electrode contacts, in relation to the midsagittal plane (lateral), the intercommissural plane (vertical), and the posterior commissure (horizontal).
Thalamic stimulation for neuropathic pain

laminectomies and a fusion from 1971 to 1975. In 1976, she fell, and during 1977 she spent 9 months in the hospital with back and leg pain. During this time she progressed from having unilateral foot drop to being almost completely paraplegic. She became bedridden, dependent on narcotics, and depressed. Arachnoiditis was diagnosed on the basis of clinical and myelographic evidence. Electrodes were implanted in first the right and then the left thalamus, since unilateral stimulation only relieves contralateral pain. She uses the stimulator twice a day now for 10 minutes on each side. Pain relief is complete during stimulation, then recurs in 6 or 8 hours. She underwent a rehabilitation program, drives a car with hand controls, and manages her household. Nine months after implantation, one of the electrodes ceased to function, but it was replaced, and she remains free of pain and active.

Case 11. This 70-year-old man suffered for 4 years from burning pain in his left leg which began when he was run over by a tractor. He was seen in the hospital several times for treatment of strictures from bladder and urethral injuries. The pelvic fractures caused dense anesthesia in all dermatomes from S-1 caudally on the left side. His complaint of pain, aggravated by walking, never changed.

In May, 1978, a thalamic electrode was implanted. He uses the stimulator about three times a day. Intermittent, sharp pains have disappeared entirely, but a steady, aching component recurs whenever he does not use the stimulator for 6 or 8 hours. He has resumed an active life.

Case 12. This 54-year-old woman complained of constant pain in the right leg and foot of 6 years’ duration. Her problem began with back and leg pain in 1956. In 1963, she had disc surgery which was the first of 10 operations on her lumbar spine. She had posterior and anterior fusions, and the lumbar spinal canal was decompressed. The final two operations in 1976 and 1977 were for subdural lysis of adhesions. She spent most of her time recumbent at home.

In 1973, she had a dorsal column stimulator implanted. Activation of this stimulator caused her upper abdominal muscles to tighten, even after the stimulator was moved at a second operation. The tingling feeling induced by stimulation occurred at the same threshold as the muscle contraction, so she was not able to use it since the muscle response seemed to cut off her breathing.

She had motor weakness in the right L-5 and S-1 distribution and sensory loss in all dermatomes caudal to L-5 on the same side. Thalamic stimulation refers paresthesias to her right trunk and leg, which completely relieves the leg pain. Some buttock pain persists. She has resumed a moderately active life.

Case 13. This 43-year-old man had pain in the left hand for 4 years, which began immediately after dynamite exploded prematurely and drove fragments of rock and metal into his arm and hand. After initial debridement, persistent pain and median nerve paralysis were treated unsuccessfully by neurolysis and sympathectomy. He avoided touching the left hand and at the time of electrode implantation he was taking 25 anileridine 25-mg tablets a day. He had been taking oxycodone compound (Percodan), 30 tablets a day, for 2 years.

His initial response to thalamic stimulation was good. Anileridine intake was reduced to three tablets a day, which he took for what he called “the jitters.” Stimulation for 15 minutes gave complete relief for about an hour. When he used the stimulator he became aware for the first time of numbness of the median nerve distribution. This sensation had been completely masked by the pain. Over the next 6 months, he could keep the pain controlled with stimulation much of the time, although when the pain was very bad, oxycodone was needed. After 3 weeks of almost total freedom from pain, he returned to his outdoor job in mining exploration. Pain returned when he got his hand very cold in wet snow. He went back on oxycodone for a few weeks and then when the pain became less severe he found that he could control it with the stimulator. He is retraining for indoor work.

Case 14. This 51-year-old sales manager had suffered pain in his right arm since he avulsed his brachial plexus in a snowmobile accident 3 years before. The burning pain would build up every hour or so until he felt as if the arm and hand were about to explode. It would stay at that intensity for a few minutes or longer. Treatment with nerve blocks, transcutaneous stimulation, and finally amputation had no effect on the pain. Analgesics were ineffective. Physical examination revealed that he had not only totally destroyed his brachial plexus but had partly injured the spinal cord, for there was some loss of pain and temperature sensation in the opposite side of his body.

Six months after implantation of a thalamic electrode, he was using his stimulator for about 30 minutes at noon when the pain would begin, and later on and off during the evening. He was sleeping well, had returned to work full time, and had resumed previously abandoned outdoor activities such as splitting wood. The daily exacerbations of sharp, burning pain had disappeared, but a dull aching pain keeps recurring and necessitates repeated use of the stimulator.

Case 15. This 58-year-old retired trainman had lumbar discectomies in 1970 and 1971 for back and leg pain. Following the second operation, bilateral leg pain and tingling of the feet developed. A laminectomy with intradural exploration in 1973 revealed adhesive arachnoiditis. The pain continued, and in 1975 he underwent more extensive laminectomy and a posterolateral fusion. Burning leg pain persisted.
Thalamic electrodes were implanted on both sides. Twice-daily stimulation relieves him of pain in the back, buttock, and posterior thigh. He can now walk without discomfort. A burning sensation in his feet persists, which he says feels more hot than painful, but is distressing.

Case 16. In 1969, this 34-year-old mechanic had the first of five operations on his lumbar spine for left-leg pain. The first and third operations were followed by long remissions. Pain recurred in 1976, and persisted despite two more decompressive procedures. The pain was always present and was aggravated by exercise. When he walked three or four blocks, pain became severe in his left buttock and ran down the back of his thigh into the lateral side of his calf. He was unable to work.

Examination revealed evidence of S-1 nerve-root damage on the left as well as restricted low-back mobility. The pain, which had been present for 2 years continuously, responded immediately to thalamic stimulation. Three months later he returned to work. He keeps entirely free of pain by using the stimulator for 8 minutes twice a day. He can now walk a mile without pain.

Case 17. This 62-year-old retired logger had for 4 years suffered continuous pain in the left leg, aggravated by walking. A series of five lumbar discectomies, fusion, and decompression operations, the first in 1953 and the last in 1968, had been partially successful until he fell and injured his back in 1975. Thalamic stimulation stopped the pain immediately, and with 10 minutes of stimulation a day, it never builds up in intensity.

Case 18. This 38-year-old man sustained skull, facial, and arm fractures in a mine explosion in 1976. He became aware of pain in the left forehead related to laceration of the supraorbital nerve when he regained consciousness a day or two after the accident. A dull constant pain “like saw blades touching the skin” was accompanied by an intermittent flashing pain. Medication and supraorbital neurectomy did not help, and by April, 1979, when a thalamic electrode was implanted, the pain had become unbearable. He completely suppresses the pain by stimulating for 10 minutes three times a day.

System Not Internalized

Case 4. This 62-year-old man sustained a fracture of T-12 with complete paraplegia when he fell from a ladder. He became aware of burning pain in his right calf and foot 2 weeks after the accident. The pain persisted and became worse.

Three years after the injury, a monopolar stimulating electrode was passed through the thalamus four times. At no time were paresthesias referred below the upper thigh, and stimulation causing thigh tingling did not influence the spontaneous lower leg pain. At a second operation 2 months later, an electrode was implanted in the medial part of the thalamus. The electrode tip was positioned 5 mm to the left of the midline, neither in front of nor behind the posterior commissure, but 2 mm below it. During 2 weeks of percutaneous stimulation, the patient found that when he turned the current up he developed a tingling feeling in the right side of the face, but this did not influence the pain in the leg. Running the stimulating current for 1 or 2 hours at or below threshold levels for facial tingling had no effect on the pain. The electrode was removed. He continued to suffer pain and died 6 months after the second thalamic operation when he deliberately took an overdose of barbiturate.

Case 5. This 73-year-old man had pain for 8 years from ophthalmic herpes zoster. The right thalamus was explored stereotaxically, but nine passages of a monopolar electrode failed to reveal a nucleus where paresthesias were referred to the face. At a second operation 2 months later, two more stimulating runs again evoked paresthesias in only the left arm and hand. An electrode was implanted in the periaqueductal gray matter, with the tip 3 mm lateral to, 1 mm behind, and 2 mm below the posterior commissure. Intermittent stimulation for 10 days failed to give pain relief, and the electrode was withdrawn. No neurological deficit resulted from the extensive thalamic exploration or the temporary insertion of the chronic electrode. The pain remains unchanged 2 years later.

Case 7. This 55-year-old man had suffered back pain for 30 years and right leg pain, which began several months before the first of two lumbar laminectomies, 6 years earlier. An electrode was implanted in his thalamus in a region where stimulation referred paresthesias to the right leg. The electrode was dislodged while being fixed to the skull and was damaged when an attempt was made 2 days later to replace it. Another electrode was not immediately available, and when one was later obtained, the patient had decided not to have the procedure repeated.

Case 10. This 69-year-old woman had a 1-year history of alternating burning heat and tingling coldness of the right side of her body which evolved from a feeling of numbness resulting, along with more transient brain-stem dysfunction, from an operation on a left posterior inferior cerebellar artery aneurysm 2 years earlier. Her skin on the right was hypersensitive to light touch. An electrode was implanted in her left thalamus where low-voltage stimulation induced a tingling sensation in the right side of her body. Stimulation did not influence the thermal dysesthesia, so the electrode was removed after a 2-week trial.

Summary of Cases

Stimulation

No pain suppression occurs if stimulation intensity is below the threshold for paresthesias in the painful
Thalamic stimulation for neuropathic pain

part of the body. At threshold, the patient has a buzzing, "electrical" feeling which is neither painful nor particularly pleasant. Higher intensity stimulation first becomes unpleasantly strong, then at even higher levels, painful. If the stimulator is set so the threshold is 7 on a scale of 10, the dial can be turned to 10 without inducing pain.

Characteristically, the pain gradually subsides during stimulation. When the pain is more severe than usual, a longer period of stimulation is required. There is little tendency for pain to recur immediately after cessation of stimulation. The patients learn to use the stimulator before the pain builds up in intensity, at a time when they "just know it is there."

Except in Case 2, when the electrode migrated, there has been no tendency for the patients to become refractory to stimulation. Most of the stimulators have been set to deliver much less than maximum power output, and it has not been necessary to increase the voltage over the course of time. Most patients set the stimulator frequency between 75 and 100 Hz.

No change in threshold of cutaneous sensory stimulation can be identified during thalamic stimulation. Even when the current is inducing intense paresthesias, cutaneous touch thresholds remain unchanged and pinprick feels sharp. Graphesthesia and simultaneous touch perception remain intact. The patient's ability to tolerate having a tendon or muscle squeezed is not altered during thalamic stimulation.

Technical Problems

Retraction of the electrode in Case 2 prompted a number of technical changes. Placement of the burr hole far enough laterally to avoid passing the electrode through the lateral ventricle during the first operation on another patient (Case 4) contributed to the difficulty in finding the target. Furthermore, he was disturbed by motor responses induced by stimulation as the electrode approached the thalamus through the internal capsule. We resumed using a parasagittal burr hole but now use the Trent Wells inserter which is thinner than the handmade inserter originally used. The electrode is placed deeper in the thalamus than in the earlier cases so that the contact point on the electrode tip is seldom used. We now loop the electrode on the brain surface deep to the point of fixation at the burr-hole cap. This prevents traction on the electrode when movement occurs between the skull and brain. To allow room for the loop, we use a burr-hole cap with a collar no more than half the thickness of the skull.

Discussion

Since our first electrode implantation in June, 1975, we have had enough experience to draw some conclusions regarding long-term effectiveness of thalamic stimulation. Patients who respond at all fall into two groups: those obtaining complete and those obtaining partial pain relief. These response patterns were discernible while the patient was still in the hospital, and there has been little tendency for change over the ensuing months.

Those who obtain partial relief observe that when their pain is severe, often as a result of vigorous activity on their part but sometimes for no apparent reason, the stimulator will not suppress it completely. Stimulation continues to eliminate their pain on other occasions when it is of its average intensity. Intermittent attacks of sharp pain usually disappear altogether, while the underlying constant ache recurs regularly, and either completely or partially responds to stimulation.

Thirteen of the 18 patients selected for thalamic stimulation obtained lasting relief from pain, either complete or partial. In the 14th patient (Case 3), the pain resolved inexplicably a few months after surgery; this patient cannot be classified as either a success or a failure. Due to technical problems, we were unable to ascertain the effect of thalamic stimulation in three patients. In two the appropriate part of the sensory nucleus could not be found, and in one the electrode was not fixed adequately. The long-term failure in one patient (Case 2), who was successfully treated for a year, likewise represents a technical breakdown, for his electrode functioned well until it retracted from his thalamus. Adams describes similar and other problems encountered in his wide experience.

The nine patients in this report whose diagnosis was lumbar arachnoiditis had had on average five lumbar spinal operations. They were selected for thalamic stimulation because of leg pain, unilateral in seven, which was attributed to nerve-root damage.

Patient selection can be deemed the cause of failure in one case. This patient (Case 10) suffered thermal dysesthesia rather than pain. Stimulation had no beneficial effect whatsoever.

Psychiatric evaluation was undertaken to help screen candidates and assess responses. Therapeutic intervention was unexpectedly needed in three of the four patients in whom permanent implantation failed; this failure of the surgical treatment triggered depression.

Although our reason for placing the electrode deep in the thalamus was to avoid electrode retraction, paresthesia can be induced at low voltages in the basal part of the ventrocaudal nucleus. For example, in Case 17 where the electrode takes a 14-mm parasagittal course, tingling in the leg was obtained at lowest voltage between the middlemost pair of contacts with an average position 1 mm below the intercommisural line. In this region, fibers from the medial lemniscus presumably are stimulated as well as thalamic neurons.

As stimulation of the sensory nucleus of the thalamus does not raise the threshold for nociceptive stimulation, it cannot be used for treatment of pain caused by noxious stimuli. Why pain remains sup-
pressed as long as 24 hours after stimulation remains unknown. The histories of repeated therapeutic failures in these patients before thalamic stimulation and the persistence of benefit beyond 3 months rules out the placebo effect as being of importance.

Richardson and Akil\textsuperscript{(12)} report that both neuropathic pain and pain of noxious origin can be suppressed bilaterally by stimulating the thalamus next to the wall of the third ventricle on one side. This is accomplished without inducing paresthesias. We tried a periaqueductal electrode in Case 5 and a medial thalamic electrode in Case 4 without success, but do not believe that our limited experience merits consideration.

Adams,\textsuperscript{(2)} Hosobuchi, \textit{et al.},\textsuperscript{(6)} and Meyerson, \textit{et al.},\textsuperscript{(12)} have demonstrated that the analgesia induced by periventricular stimulation can be blocked by naloxone, a morphine antagonist. Meyerson, \textit{et al.},\textsuperscript{(12)} found this to be true in three patients with cancer pain, while Adams\textsuperscript{(2)} described it in one patient with diabetic neuropathy. Hosobuchi, \textit{et al.},\textsuperscript{(4)} demonstrated that if the periventricular stimulator is used continuously, tolerance develops and this tolerance coincides with the development of tolerance to narcotics.

Richardson and Akil\textsuperscript{(12)} stress that patients must abstain from narcotics in order to benefit from periventricular stimulation. We have not observed any relationship between narcotic use and short-term efficacy of stimulation. One patient (Case 13) was addicted and continues to use narcotics to supplement stimulation from time to time.

Boethius, \textit{et al.},\textsuperscript{(4)} reported pain relief and reduction of dysesthesia from long-term stimulation of the sensory thalamus or internal capsule in four of five patients with neuropathic pain. Their observation that sensory thresholds remained unchanged during stimulation agrees with our finding. This may reveal a difference between the mode of action of sensory thalamic stimulation and periventricular stimulation, although Hosobuchi, \textit{et al.},\textsuperscript{(4)} could not confirm the elevation in cutaneous pain threshold during periventricular stimulation described by Richardson and Akil.\textsuperscript{(12)}

Hosobuchi, \textit{et al.},\textsuperscript{(4)} have shown that periaqueductal stimulation elevates the concentration of \(\beta\)-endorphin in ventricular fluid, while internal capsular stimulation which they employ for deafferentation pain does not. If the morphine-like character of periventricular stimulation suggests a chemical mechanism of action, the lack of apparent interaction with narcotics and the lack of bilateral response to sensory thalamic stimulation would suggest a different mode of action.

Melzack\textsuperscript{(10)} proposed a mechanism for deafferentation pain, which he later modified and expanded in a review article with Loeser.\textsuperscript{(11)} They presented evidence that nerve damage to sensory pathways may cause prolonged hyperactivity in dorsal horn cells and sensory nuclei central to the lesion. These hyperactive neuronal pools act as pattern-generating mechanisms that give rise to localized pain even if later isolated from the original nerve injury by surgical means. These central pattern-generating mechanisms are subject to inhibition. Not only does thalamic stimulation appear to provide such inhibition, but when the pain is temporarily suppressed, natural inhibitory mechanisms such as proprioceptive inputs from active limbs can be brought into action.

Laboratory studies are required to ascertain the precise mechanism whereby thalamic stimulation suppressed neuropathic pain. An important question to answer is why do most individuals with injuries to sensory pathways experience numbness without pain, while others develop pain that worsens as time passes.

Previous reports that neuropathic pain can be suppressed by stimulation of the sensory nucleus of the thalamus\textsuperscript{(7,9)} or its projection in the internal capsule\textsuperscript{(1)} have been confirmed. Richardson and Akil\textsuperscript{(12)} have published impressive results from periventricular stimulation in patients with a wide range of pain problems, including varieties that would not be suitable for sensory thalamic stimulation therapy. Their findings have been supported.\textsuperscript{(6,12)} Which of these targets will be most used in the future remains to be seen. There can be little doubt that thalamic stimulation will continue as a treatment for intractable pain.

\textbf{References}

Thalamic stimulation for neuropathic pain


The treatment described was initially undertaken on an experimental basis with a grant provided by the British Columbia Medical Services Foundation.

Address reprint requests to: Ian Turnbull, M.D., Division of Neurosurgery, Department of Surgery, 700 West 10th Avenue, Vancouver, British Columbia, Canada V5Z 1L5.