Sensory and motor responses to deep brain stimulation
Correlation with anatomical structures

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Motor and sensory responses induced by trial stimulation were examined before stereotaxically implanting
a permanent stimulating electrode for pain relief in 11 patients with intractable pain of central origin. The
total number of points eliciting a response when stimulated was 70. The points of stimulation were determined
as exactly as possible from Schaltenbrand and Bailey's Atlas. Motor responses were detected upon stimulating
21 points, the majority of which were in the posterior third of the posterior limb of the internal capsule (IC).
Stimulation of these 21 points was accompanied by pain relief in only two points (10%). Warm (22) or cool
sensations (three) were provoked in the most posteromedial portion of the posterior limb of the IC, nucleus
reticularis pulvinaris, and area triangularis, and seven (28%) of these 25 sensations were accompanied by pain
relief. A burning sensation was found upon stimulation of 12 points, with stimulation in the mesencephalic
lateral tegmental field eliciting the most severe burning pain. A tingling sensation was elicited at 12 points, in
a distribution similar to that of the warm sensation. Five (42%) of these 12 points provided pain relief. The
best stimulating point for pain relief is not in the center of the posterior limb of the IC, directly lateral to the
posterior commissure, but rather in its most posteromedial part; that is, at the nucleus reticularis pulvinaris or
area triangularis.

KEY WORDS • sensory response • motor response • electrical stimulation •
pain relief • intractable pain • thalamic pain

STIMULATION of various deep brain structures was
introduced in the early 1970’s for pain relief in
patients with intractable pain.2,6,10-12,16 The pos-
terior limb of the internal capsule (IC),1,2,6,11 thalamic
sensory nuclei,1,10-12,16,19 and mesencephalic lemniscus
medialis13 are known as structures that provide excel-
lent pain relief. Nevertheless, there are few reports that
correlate the exact point of stimulation in the deep
brain structure to the kind of sensation evoked.

Stimulation, predominantly of the posterior limb of
the IC, and, on occasion, the thalamic sensory nuclei
or mesencephalic lemniscus medialis, has been per-
formed on our neurosurgical service in patients with
intractable pain of central origin. The site of stimulation
was determined by reference to the Schaltenbrand and
Bailey Atlas,17 and the motor or sensory response to
each stimulated site was assessed. It is the purpose of
this report first to identify the best target point for
stimulation based on the Atlas, and second to reeval-
uate the previously described fiber arrangement in the
posterior limb of the IC.

Clinical Material and Methods

A summary of the 11 patients (nine men and two
women, average age 53 years) treated with deep brain
stimulation is presented in Table 1. The method of
stimulation has been described elsewhere.15 Before im-
planting a permanent stimulating electrode by stereo-
taxic surgery, trial stimulation, using 500 Kohm to 1
Mohm, was applied through a temporary 1.5-mm bi-
polar electrode inserted in the brain. The inner electrode
was always the cathode (Fig. 1). The temporary stimu-
lation electrode was first aimed at the postulated target
point, 25 mm directly lateral to the midline of the
posterior commissure (PC). The efficacy of stimulation
of this target point and of points on the same trajectory
but a few millimeters deeper or shallower (usually in
Responses to deep brain structure stimulation

TABLE 1
Summary of patients treated by deep brain stimulation

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs) at Admission, Sex</th>
<th>Attributable Etiology</th>
<th>Type of Pain</th>
<th>Duration of Pain to Op</th>
<th>Stimulation Site*</th>
<th>Pain Relief† (on discharge)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53, M</td>
<td>lt thalamic hemorrhage</td>
<td>hyperpathia, dysesthesia, spontaneous pain</td>
<td>7 yrs 10 mos</td>
<td>lt IC</td>
<td>excellent</td>
</tr>
<tr>
<td>2</td>
<td>53, M</td>
<td>rt thalamic hemorrhage</td>
<td>hyperpathia, spontaneous pain</td>
<td>3 mos</td>
<td>rt IC</td>
<td>excellent</td>
</tr>
<tr>
<td>3</td>
<td>63, F</td>
<td>rt thalamic infarction</td>
<td>hyperpathia, spontaneous pain</td>
<td>3 mos</td>
<td>rt IC</td>
<td>good</td>
</tr>
<tr>
<td>4</td>
<td>64, M</td>
<td>rt thalamic infarction</td>
<td>spontaneous pain</td>
<td>4 mos</td>
<td>rt IC</td>
<td>fair</td>
</tr>
<tr>
<td>5</td>
<td>63, M</td>
<td>rt putaminal &amp; IC infarction</td>
<td>spontaneous pain</td>
<td>1 yr 4 mos</td>
<td>rt IC</td>
<td>good</td>
</tr>
<tr>
<td>6</td>
<td>59, M</td>
<td>rt thalamic hemorrhage</td>
<td>dysesthesia, spontaneous pain</td>
<td>4 yrs</td>
<td>rt IC</td>
<td>fair</td>
</tr>
<tr>
<td>7</td>
<td>48, M</td>
<td>lt putaminal hemorrhage</td>
<td>spontaneous pain</td>
<td>4 yrs 7 mos</td>
<td>lt IC, lt VPL, LM</td>
<td>poor‡</td>
</tr>
<tr>
<td>8</td>
<td>44, M</td>
<td>rt cortical &amp; subcortical hemorrhage</td>
<td>hyperpathia, dysesthesia, spontaneous pain</td>
<td>5 mos</td>
<td>rt IC, rt VPL, LM</td>
<td>good</td>
</tr>
<tr>
<td>9</td>
<td>33, F</td>
<td>multiple sclerosis</td>
<td>hyperpathia, spontaneous pain</td>
<td>2 yrs</td>
<td>rt IC, rt VPM</td>
<td>poor</td>
</tr>
<tr>
<td>10</td>
<td>55, M</td>
<td>lt thalamic hemorrhage</td>
<td>hyperpathia, dysesthesia, spontaneous pain</td>
<td>10 mos</td>
<td>lt IC</td>
<td>excellent</td>
</tr>
<tr>
<td>11</td>
<td>50, M</td>
<td>rt thalamic hemorrhage</td>
<td>spontaneous pain</td>
<td>3 yrs 1 mo</td>
<td>rt IC</td>
<td>poor</td>
</tr>
</tbody>
</table>

*IC = posterior limb of the internal capsule; VPL = nucleus ventralis posterolateralis; LM = lemniscus medialis; VPM = nucleus ventralis posteromedialis.
† Excellent: complete pain relief; good: pain was incompletely relieved with occasional necessity of analgesics; fair: pain was incompletely relieved with frequent necessity of analgesics; poor: no pain relief.
‡ In Case 7, center median thalamotomy, pulvinotomy, and mesencephalic lemniscal tractotomy were performed.

2.5-mm steps) was examined. If no point on the first trajectory gave satisfactory pain relief, the electrode was placed on another trajectory. The total number of trajectories in these 11 patients was 21: 14 toward the posterior limb of the IC (Fig. 2 left), and seven toward the thalamic sensory nuclei, pulvinar, or mesencephalic lemniscus medialis (Fig. 2 right).

Case Reports

Case 1
This 53-year-old man suddenly developed a right hemiparesis and hemihypesthesia in 1972, which was diagnosed as being due to a thalamic hemorrhage. Eight months after the attack, he began to complain of an uncomfortable and irritable sensation in his right arm and shoulder which became progressively more intense.
Fig. 2. Lateral view of the trajectories toward the posterior limb of the internal capsule (left) and other target points (right). The dots show the deepest point of the insertions. CA = anterior commissure; CP = posterior commissure; Fo.M = foramen of Monro. Left: Fourteen trajectories in 11 patients are shown; two trajectories have been deleted because of overlapping. Note that the electrode was frequently inserted beyond the CA-CP line. Right: Seven trajectories in three patients are shown. The most posterior track is aimed at the pulvinar. The four deep points are in the mesencephalic lemniscus medialis and lateral tegmental field. The others are directed toward the thalamic sensory nuclei.

This 53-year-old man suddenly developed paresthesias (tingling sensations) in the left extremities due to a thalamic infarction. Hyperpathia and spontaneous pricking pain developed soon after the attack (Fig. 3 upper row, a). A CT scan on admission in September, 1981, revealed no abnormality (Fig. 3 lower row, b). Stimulation in the posterior limb of the IC at 50 Hz, 0.2 msec, and 1 to 2 V for 20 seconds elicited a warm sensation (two points). The patient reported that she felt as if she was immersed in hot water. Advancing the electrode elicited a comfortable warm sensation with significant pain relief, and a permanent electrode was implanted there since further advance provided less relief (Fig. 3 lower row, c).

Case 3

This 63-year-old woman suddenly developed paresthesias (tingling sensations) in the left half of his body as if the patient was being fanned. The hemiplegia improved very soon, but 5 months later he began to complain of intense spontaneous burning pain (Fig. 4 upper row, a). A CT scan on admission in June, 1982, demonstrated a low-density area deep in the temporo-occipital region, partially involving the posterothalamic thalamus (Fig. 4 upper row, b). Stimulation of the external capsule at 50 Hz, 0.2 msec, and 2 to 4 V for 20 seconds (two points) provoked motor responses (blepharospasm of the left side and muscle contraction of the left arm) as well as a slight warm sensation spreading from the toes toward the thigh; however, no pain relief was obtained. Advancing the electrode (two points in the putamen, one in the posterior limb of the IC, and two in the nucleus reticularis pulvinaris) elicited a warm sensation in both legs, predominantly on the left side. The spontaneous pain still was not relieved. The electrode was then placed 2 to 3 mm medial to the first trial site. On this trajectory, putaminal stimulation provoked a muscle contraction of the left arm and side of the face, accompanied by a slight tingling sensation. Stimulation at the border between the putamen and the posterior limb of the IC gave only a tingling sensation. Stimulation of the IC elicited a cool sensation over the left half of the body as if the patient was being fanned. Spontaneous pain was reduced. Further advance of the electrode (two points) elicited a similar cool sensation over the entire body (Fig. 4 upper row, c). The patient was free from pain as long as the stimulation was continued; however, pain recurred shortly after cessation of the stimulation.
Responses to deep brain structure stimulation

**Case 1**

![Image of Case 1](image)

**Case 2**

![Image of Case 2](image)

**Case 3**

![Image of Case 3](image)

**Fig. 3.** Cases 1, 2, and 3. The distribution of pain and sensory disturbance is shown (left column, a), the computerized tomography (CT) findings on admission are illustrated with the area of pathology indicated (arrows) (center column, b), and the type of response evoked by stimulation of each point on the trajectory is projected on the Schaltenbrand and Bailey Atlas (right column, c). In (a), dots show areas of hypesthesia, and lines show areas of hyperpathia, dysesthesia, or spontaneous pain. In (c), circles indicate a warm sensation, triangles a motor response (muscle contraction), and squares a tingling sensation. Solid symbols show the points that provided pain relief by stimulation, and asterisks the point where the permanent stimulating electrode was implanted.

**Case 5**

This 63-year-old man suddenly developed a left hemiparesis and hemisensory disturbance due to a thalamic infarction, followed 2 months later by severe burning pain (Fig. 4 center row, a). A CT scan on admission in October, 1982, revealed a small low-density area in the posterior limb of the IC with partial involvement of the putamen (Fig. 4 center row, b). Stimulation of the posterior limb of the IC as well as of points between the IC and putamen or nucleus reticularis pulvinaris (three points) at 50 Hz, 0.2 to 0.5 msec,
and 2 to 4 V for 20 to 30 seconds elicited muscle contraction of the affected side. Stimulation of the nucleus reticularis pulvinaris (one point) or area triangularis (of Wernicke) (two points) elicited a warm sensation, starting from the toes and going upward to the shoulder, with simultaneous reduction of pain (Fig. 4 center row, c).

Case 6

This 59-year-old man was admitted in November, 1982, suffering from a severe spontaneous pricking pain and dysesthesia over the entire left half of the body (Fig. 4 lower row, a). He had begun to complain of such pain 1 month after a right thalamic hemorrhage which had occurred 4 years before. A CT scan on admission revealed a small low-density area in the posterior thalamic region (Fig. 4 lower row, b). Stimulation of the dorsal putamen at 50 Hz, 0.5 msec, and 2 to 4 V for 20 seconds provoked a muscle contraction. Advancing the electrode through the putamen into the IC (four

![Fig. 4. Cases 4, 5, and 6. The symbols have the same meaning as in Fig. 3. In Case 4 (c), the three circles on the medial trajectory represent a cool sensation, and the asterisk on the trajectory in Case 6 (c) shows the point with a burning sensation (pain).]
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points) elicited a burning or very hot sensation without any relief of pain. Further advance 2 to 3 mm beyond the PC level into the nucleus reticularis pulvinaris elicited a warm sensation with simultaneous disappearance of dysesthesia; however, the spontaneous pain was not relieved at all (Fig. 4 lower row, c).

Case 7

This 48-year-old man developed a severe spontaneous burning pain on the right half of the body including the face after an extensive putaminal hemorrhage which was removed in August, 1979 (Fig. 5 upper row, a and b). The patient was admitted in May, 1983, and a permanent stimulating electrode was implanted in the posterior limb of the IC. Stimulation proved completely ineffective; therefore, the electrode was withdrawn. He was readmitted in February, 1984. Trial stimulation on the trajectory toward a point 25 mm directly lateral to the midline of the PC did not provoke any kind of motor or sensory response. The electrode was replaced medially and anteriorly (Fp 10.0). Stimulation of the nucleus reticularis thalami and nucleus ventralis caudalis externa at 50 Hz, 0.5 msec, and 2 to 4 V for 20 to 30 seconds provoked a muscle contraction (three points), and the patient felt as if his arm and leg tightened up. Advancing the electrode into the zona incerta elicited a burning sensation. Lateral movement of the electrode into the putamen and pallidum provoked a similar contractive sensation (three points) (Fig. 5 upper row, c left). The electrode was reinserted aiming at a point between the nuclei ventralis caudalis externa and interna (Fp 13.0). Stimulation of these thalamic sensory nuclei on this trajectory elicited no motor or sensory response, even when the stimulating voltage was gradually increased to 5 to 6 V. Advancement of the electrode far beyond the PC level into the lateral mesencephalic tegmental field, just medial to the lemniscus medialis, provoked a severe burning sensation (two points) even with a very low voltage stimulation of 1 V (Fig. 5 upper row, c right). In this particular patient, a center median thalamotomy and mesencephalic lemniscal tractotomy were performed afterward,

![Image of diagrams for Cases 7, 8, and 9]

**Fig. 5.** Cases 7, 8, and 9. The *symbols* have the same meaning as in Fig. 3. In these three patients, the trajectory was changed more than three times to obtain optimal pain relief. Nevertheless, no pain relief was achieved in Cases 7 and 9. A center median thalamotomy, mesencephalic lemniscal tractotomy, and pulvinotomy were subsequently performed in Case 7. Stimulation of the mesencephalic lateral tegmental field in Cases 7 and 8 elicited severe burning pain.
providing no pain relief. Finally, the nucleus centralis medialis of the pulvinar was stimulated (Fig. 2), also giving no pain relief. A pulvinotomy was moderately effective in this patient.

**Case 8**

This 44-year-old man developed dysesthesia, hyperpathia, and spontaneous pricking pain of the left hand, arm, and face after a hemorrhage in the right cerebral sensory cortex (Fig. 5 center row, a and b). The patient was admitted in January, 1984. Stimulation of the posterior limb of the IC at 50 Hz, 0.2 msec, and 2 to 4 V for 20 seconds elicited muscle contraction (two points) and a moderate burning sensation of the left lower limb (two points) (Fp 10.0, Fig. 5 center row, c right). Medial and posterior replacement of the electrode (Fp 13.0) provoked a similar burning sensation in the same area (two points). Stimulation of the mesencephalic lateral tegmental field elicited severe burning pain (one point). Finally, the electrode was placed in the mesencephalic lemniscus medialis. Stimulation of the thalamic sensory nuclei, through which the electrode was introduced into the lemniscus medialis, elicited no motor or sensory response. Stimulation of the lemniscus medialis, where a permanent electrode was implanted, provided a warm sensation covering the left upper half of the body, including the hand, fingers, and face, with considerable relief of pain (Fig. 5 center row, c left).

**Case 9**

This 33-year-old woman, who had been suffering from multiple sclerosis, began to complain of hyperpathia and spontaneous pricking pain, predominantly over the face, head, and shoulders, 1 year after the onset of the disease (Fig. 5 lower row, a). A CT scan on admission in May, 1982, demonstrated no abnormality (Fig. 5 lower row, b). Stimulation of the right side of the dorsal putamen (Fp 13.0) at 50 Hz, 0.2 msec, and 2 to 6 V for 20 seconds elicited a muscle contraction of the left arm. The patient reported difficulty in moving her fingers and hand. Advancing the electrode through the ventral putamen into the IC provoked a warm sensation in the left extremities with a slight unpleasant tingling sensation (three points). Medial replacement of the electrode along the outer border of the thalamus only elicited similar motor responses or a tingling sensation (Fig. 5 lower row, c left). Finally, the electrode was reinserted in the nucleus ventralis caudalis interna (Schaltenbrand and Bailey, Fp 10.0), but only an uncomfortable tingling sensation was elicited by any of the stimulations (Fig. 5 lower row, c right).

**Case 10**

This 55-year-old man suffered from hyperpathia, dysesthesia, and spontaneous pricking pain (Fig. 6 upper row, a) after a left thalamic hemorrhage. A CT scan on admission in June, 1984, demonstrated a low-density area in the posterolateral thalamic region (Fig. 6 upper row, b). The pain became more and more intense until the operation. In this particular patient, a trial stimulation at 50 Hz, 0.2 msec, and 2 to 3 V for 20 seconds first given to a point 20 mm directly lateral to the midline of the PC, which was believed to be the nucleus reticularis pulvinaris (Fig. 6 upper row, c), elicited complete pain relief accompanied by a tingling sensation. No other site was tested for stimulation.

**Case 11**

This 50-year-old man was admitted in July, 1984, complaining of a spontaneous uncomfortable sensation in the left half of the body, especially on walking, which became apparent 9 months after an intracerebral hemorrhage (Fig. 6 lower row, a). A CT scan on admission demonstrated a low-density area in the suprathalamic region with partial involvement of the upper portion of the thalamus (Fig. 6 lower row, b). Stimulation of a point 20 mm directly lateral to the midline of the PC, in the nucleus reticularis pulvinaris, at 50 Hz, 0.5 msec, and 2 to 4 V for 20 to 30 seconds elicited complete pain relief with a tingling sensation on the affected side at the time of the operation (Fig. 6 lower row, c). However, in this patient, sensations evoked during the trial stimulation period varied significantly from one time to another, so that the efficacy of the stimulation seemed doubtful.

**Summary of Results**

A total of 70 points elicited a motor response (muscle contraction) or a sensory response (warm, hot, cool, tingling, or burning sensation) in these 11 patients. A motor response with the patients reporting a contractive sensation of the muscle accompanied by difficulty in moving the part was elicited by stimulation of 21 points (Fig. 7A). Most of the points were located in the posterior third of the posterior limb of the IC. Some were scattered in the putamen and posterolateral thalamic nuclei. Stimulation of these points was usually not associated with pain relief except for two points in Case 2 (for a pain relief of 10%). The points that elicited a warm (20), cool (three in Case 4), or hot (two) sensation were mainly distributed in the posterior and medial portion of the posterior limb of the IC, and nucleus reticularis pulvinaris or area triangularis (of Wernicke). Stimulation of seven of these points (28%), including one point in the mesencephalic lemniscus medialis, was associated with pain relief (Fig. 7B). A burning sensation was provoked by the stimulation of 12 points in various structures (Fig. 8A). Burning pain was typically elicited in the mesencephalic lateral tegmental field (Case 7). The burning sensation was always uncomfortable for the patient and was never accompanied by pain relief. A tingling sensation (Fig. 8B) was obtained by stimulation of 12 points distributed in the postero-medial portion of the posterior limb of the IC, nucleus reticularis pulvinaris, and area triangularis (of Wernicke).
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Case 10

Fig. 6. Cases 10 and 11. The symbols have the same meaning as in Fig. 3. In these two patients, trial stimulation was first applied at a point 20 mm directly lateral to the midline of the posterior commissure, at which satisfactory pain relief with a tingling sensation was elicited at the time of the operation.

Discussion

It has been found previously that, with the electrodes used in this study, electrical current spread no more than 2 mm from the point of stimulation with application parameters of less than 4 to 5 V, 50 Hz, and 0.2 to 0.5 msec. This limit seems to have been confirmed in Case 4, in which replacement of the electrode 2 to 3 mm medial to the previous trajectory elicited the opposite sensation: a warm sensation before and a cool sensation after the electrode was replaced. Furthermore, as the electrode was advanced or withdrawn in 2.5-mm steps, the evoked response obtained was often quite different at each step.

The position of the internal capsule and other structures around it varies considerably among individuals, depending on the width of the third ventricle. Hardy, et al., reported a trend for the medial internal capsule border to shift laterally as the third ventricle increased in size, referring to the inaccuracy of the Schaltenbrand and Bailey Atlas in some instances. It should be emphasized, though, that the Schaltenbrand and Bailey Atlas is based on many different cadaver brains, so that the coronal, sagittal, and horizontal planes illustrated show some discrepancies. However, there is no method for estimating a particular position in deep brain structures other than with the use of this Atlas. It seems important to keep these facts in mind when determining the exact point of stimulation. Our trial target point was 25 mm directly lateral to the midline of the posterior commissure (PC), as described by Adams and Hosobuchi. When stimulation through this trajectory elicited no pain relief, another site was tested for stimulation by changing the stimulating trajectory. In Cases 10 and 11, however, the electrode was first placed 20 mm directly lateral to the midline of the PC because the authors thought that stimulation of a more medial part of the IC might provide better pain relief. Adams, et al., placed the electrode at various points 20 to 27 mm directly lateral to the midline of the PC.
efficacy varied from one case to another with no consistent pattern. Tsubokawa, et al., preferred stimulation of the thalamic sensory nuclei, based on experimental and clinical data demonstrating that stimulation of these nuclei inhibits not only central, but also peripheral pain. On the other hand, Mundinger and Salomão recommended the mesencephalic medial lemniscus. Our sites of stimulation were distributed in all of these areas.

Motor responses were mainly obtained by stimulation in the posterior one-third of the posterior limb of the IC. This result seems to be coincident with the finding of Englander, et al., and Hardy, et al., who indicated that all of the motor fibers, including the corticobulbar tract, are compactly located in the posterior third quarter of the posterior limb of the IC. Scattered points with motor responses in the putamen might reflect the inaccuracy of the Schaltenbrand and Bailey Atlas. Motor responses seldom accompanied pain relief. A comfortable warm or cool sensation was mainly elicited by stimulation of the posterior and medial portion of the posterior limb of the IC as well as the posterolateral region of the thalamus. The posteromedial part of the posterior limb of the IC is described by Hardy, et al., and Tasker and Emmers as the portion through which fibers from the thalamic sensory nuclei pass to the cerebral cortex. Nevertheless, the warm and cool sensations were not always associated with pain relief. Pain relief was most often obtained in or near the nucleus reticularis pulvinaris or area triangularis (of Wernicke) in this study. Of seven points that gave pain relief on stimulation, five were located in these nuclei. The physiological characteristics of these nuclei are not yet known; however, they seem to have a close anatomical relationship with the pulvinar thalami. Fibers from these nuclei surround the lateral geniculate body and run toward the pulvinar thalami. Stimulation of the mesencephalic lemniscus medialis in Case 8 elicited pain relief with a comfortable warm sensation, as Mundinger and
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Salomão\textsuperscript{13} have also described. A burning sensation (pain) was obtained by stimulation of various sites in the deep brain structures, the most intense pain being elicited by even weak stimulation of the lateral mesencephalic reticular formation. According to Amano, et al.,\textsuperscript{3,4} there are many synaptic terminals of the spinothalamic tract in the rostral mesencephalic tegmental field, stimulation of which provokes severe pain. The distribution of areas associated with a tingling sensation was similar to that of areas associated with warm and cool sensations. These areas were located mainly in the nucleus reticularis pulvinaris, area triangularis (of Wernicke), and the posterior portion of the posterior limb of the IC. Stimulation of thalamic sensory nuclei is said to be almost always accompanied by a tingling sensation and relief of intractable pain.\textsuperscript{19,20} However, in Case 7, no sensory or motor response was obtained from two stimulation trials.

**Conclusions**

Pain relief was often accompanied by a tingling sensation and a warm or cool sensation. Our trial target point was at the PC level; however, pain relief was frequently achieved by stimulation a few millimeters below this level. Thus, it is believed that the best target point is actually not in the center of the posterior limb of the IC but in the postero-medial part of the IC, the nucleus reticularis pulvinaris, and the area triangularis. The latter two nuclei probably have a close relationship with the pulvinar thalami,\textsuperscript{17} although the physiological function of these nuclei remains to be clarified. The arrangement of motor and sensory fibers in the posterior limb of the IC seemed to be coincident with previous reports.\textsuperscript{5,7,8,18}

**References**


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