Surgical treatment guided by spinal cord evoked potentials for tetraparesis due to cervical spondylosis

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Sixteen consecutive patients who were unable to ambulate independently due to cervical spondylotic myelopathy were treated surgically with the guidance of spinal cord evoked potentials (SCEPs). The SCEPs were recorded intraoperatively with needle electrodes inserted into serial cervical intervertebral discs after caudal epidural stimulation. Despite the presence of multiple extradural defects and/or cord compression seen on MRI, anterior decompression followed by fusion was able to be focused on a single level where the distinct change in waveform of the SCEP suggestive of spinal conduction block was revealed. Excellent neurological improvement resulted from the operation and all patients followed up for a period of more than 6 months were found to be ambulatory without walking aids.

Keywords: cervical spondylosis; myelopathy; tetraparesis; spinal cord; evoked potentials; conduction block

Introduction

The most serious consequence of cervical disc degeneration is cervical spondylotic myelopathy (CSM). Although the onset is usually insidious, the spinal cord disorder associated with cervical spondylosis may develop within a year into a condition as devastating as a spinal cord injury. When spondylosis involves multiple levels as is quite often the case in elderly patients, operative intervention is commonly considered to be necessary over multiple levels by either an anterior or a posterior approach. Since compromising structures which are added on a constitutionally narrow canal usually lie ventral to the cord,¹ an anterior approach with decompression followed by fusion would usually be the procedure of choice. However, an increasing rate of non-union as well as other adverse effects is noted when fusion is attempted at more than one disc level.^{2–4} It would seem reasonable to assume that all compressive structures such as protruding disc material, osteophytes, or hypertrophied ligamentum flavum are not offending, since it is known that correlation is lacking between the severity of the spondylosis and the severity of the paraparesis.⁵ The advent of magnetic resonance imaging (MRI) is obviously very helpful in defining where the spinal cord is compressed, but the compression may extend over multiple spinal segments. There is evidence that a variety of abnormalities seen on MRI can be asymptomatic.⁶

Conduction block, the arrest of impulse propagation along intact axons, is known to be one of the most important causes of clinical weakness and sensory loss. In compression syndromes of peripheral nerves, localization of the precise site of compression has been best

achieved by serial short increment stimulation searching for focal conduction abnormalities.⁷ Similarly, in CSM with more than a moderate degree of spastic tetraparesis the vertebral level responsible for the myelopathic condition can be disclosed by demonstrating major focal conduction block. We have made an attempt prospectively, therefore, to focus the surgical intervention only at the level where spinal cord evoked potentials (SCEPs) have given us evidence of conduction block.

Methods

Patients

Sixteen consecutive patients who were unable to ambulate independently prior to surgery were included in this series. Fourteen of them required walking aids (Nurick grades 3, 4) and two were chairbound (Nurick grade 5). All patients, with an average age of 72 years (range 58–81), were treated between August 1991 and December 1993 by means of anterior cervical decompression and fusion which was focused on a single vertebral level with the guide of SCEPs as well as MRI studies. The duration of symptoms prior to surgery averaged 4.5 months (range 1–9).

Electrodiagnosis

Following general anaesthesia and preceding the operation, the stimulating electrode, with two platinum tips at the end of a 18 gauge polyethylene tube,⁸ was introduced percutaneously through a Tuohy needle (Hakko Shoji Co, Osaka, Japan) to place the tip of the

electrode into the epidural space⁹ at the lower thoracic or upper lumbar level.

When the cervical discs and vertebral bodies were exposed during the course of the operation, the recording disposable sensory needle electrodes (Dantec 13R23, Dantec Medical, Skovlunde, Denmark) were inserted into serial intervertebral discs.¹⁰ The needle was advanced posteriorly the same length as the sagittal diameter of the corresponding disc calculated beforehand from measurement of the plain radiograph (Figure 1). Additional needles (Dantec 13R21) were placed for reference into the longus colli muscle at about the same levels as the active electrodes. Electrical stimulation of a square wave, 0.1 ms in duration and some 20 mA in intensity, was delivered at a rate of 20 per s. A multichannel averager (Dantec Evomatic 8000) allowed simultaneous recordings of SCEPs from the intervertebral discs. Each test set comprised an average of 100 or 200 summated potentials with a frequency response of 20 Hz–5 KHz (3 dB down). Two tracings obtained for each electrode deviation confirmed consistency.

Surgical procedure and postoperative care

The discectomy at the exact level responsible for the myelopathy was followed by partial corpectomies of the adjacent vertebrae using a high-speed drill. The height of each corpectomy was from one third to one half of

the vertebral height and its width was at least 15 mm, which allowed adequate visualization and space for the decompression from all compromising structures. After removing the bony cortex safely with the aid of magnifying loupes or a microscope, the posterior longitudinal ligament was fully exposed. The decompression was completed with incision of the ligament in the shape of a cross and then its partial removal, which enabled the dura to bulge into the decompression. Finally, a piece of horseshoe-shaped tricortical iliac bone graft was tapped into the intervertebral space which had been widened by a spreader.

Patients were allowed up with a moulded cervico-thoracic orthosis in place within a week after surgery. It was worn for the first 2 months followed by immobilization with a cervical collar until fusion occurred, usually after another 1 or 2 months.

Results

All patients showed the distinct change in waveform of the SCEPs suggestive of a spinal conduction block, which was either an abrupt reduction in amplitude or the enhanced monophasic positive wave known as killed-end potential,^{11,12} (Figure 2, 3). The former type of change was more frequently encountered (11/16 patients) than was the latter (5/16 patients).

The intervertebral levels where the conduction block was revealed were C3–4 in nine patients, C4–5 in four, C5–6, C6–7 and C7–T1 in one each. They were closely related to the compression levels as shown by MRI investigation. In all but two patients, the waveform alteration of the SCEPs occurred at exactly the same level where MRI studies demonstrated the most prominent compression of the spinal cord (Figure 2). In one of the two exceptional patients, the degree of cord flattening at the C5–6 level was equal to or even exceeded that at the C3–4 level where the SCEPs showed a conduction block (Figure 3). In the other patient, the spinal cord was evenly compressed at C4–5, C5–6 and C6–7 levels, whereas a sagittal T2-weighted MRI demonstrated a high-intensity signal of the cord segment at the C4–5 level where the conduction block was revealed. Increased signal intensity in T2-weighted images of the cord secondary to compression¹⁴ was observed in seven patients. In all of them, the level of an abnormal T2 signal coincided with that of conduction block.

Every patient was treated by single-level anterior decompression followed by fusion. One patient died of renal cancer 3 months after spinal surgery. The remaining 15 patients were observed over an average period of 18 months (range 6–28). In all these patients graft incorporation was attained within 4 months, verified by plain lateral radiographs of the cervical spine taken in full flexion and then in extension, revealing an invariable distance between spinous processes of the level fused. Although two patients were chairbound and 13 were unable to stand or ambulate without aids prior to the surgery, all patients became ambulatory without walking aids. The overall results of

Figure 1 Lateral cervical spine roentgenogram taken in the operating room showing needle electrodes inserted into intervertebral discs as the active electrodes for intraoperative recordings of the SCEPs

Figure 2 (a) A 73-year-old man with a 9 month history of clumsy hands and a few months' inability to ambulate without a frame (Nurick grade 4). T2-weighted MRI (left) demonstrates the multiple extradural defects referred to as washboard spine.¹³ Sagittal (middle) and axial (right) T1-weighted MRIs show marked compression of the cord at the C3-4 intervertebral level. (b) Superimposed averaged SCEPs recorded intraoperatively from the discs after caudal epidural stimulation (left), and a roentgenogram taken 18 months postoperatively (right). Note the monophasic positive waves at the C3-4 level in contrast with normal waveforms at the C4-5, C5-6, and C6-7 levels. With anterior decompression followed by fusion only at the C3-4 level, the patient became ambulatory without difficulty (Nurick grade 1)

Figure 3 (a) A 68-year-old man with a 2 month history of clumsy hands and inability to ambulate without a frame (Nurick grade 4). Sagittal T2-weighted (left) and T1-weighted (middle) MRIs demonstrate the evenly prominent cord compression at C3-4 and C5-6 intervertebral levels. Axial T1-weighted MRIs (right) show that the degree of cord flattening at the C5-6 level exceeds that at the C3-4 level. (b) Superimposed averaged SCEPs recorded intraoperatively (left) and a roentgenogram taken 4 months postoperatively (right). Abrupt reduction in amplitude of the SCEP negative peak at the C3-4 intervertebral level suggests that the C3-4 level is responsible for the myelopathic condition. With single-level anterior decompression followed by fusion, the patient became ambulatory without any difficulty (Nurick grade 1)

15 patients are shown using the functional grading of Nurick⁵ (Figure 4).

Discussion

The clinical outcome of patients with nerve lesions usually depends on the degree of axonal destruction.¹⁵ There is a better prognosis for those with cervical spondylotic myelopathy causing tetraparesis than for those who have had traumatic spinal cord injury. It is suggested, therefore, that conduction block, the

terminology implicitly meaning the intact axon, is most often the cause of clinical weakness and sensory loss in CSM unless the symptoms have been present for a long time.

In the present study we have shown that spinal conduction block and its localization can be disclosed using the SCEPs recorded from serial intervertebral discs of the cervical spine after caudal epidural stimulation.¹⁰ For intraoperative spinal cord monitoring, it is known that placement of both stimulating and recording electrodes in various structures around the spinal

Figure 4 Surgical outcome evaluated according to the disability scale of Nurick.⁵ (Grade 0: No evidence of cord involvement. Grade 1: Signs of cord involvement with normal gait. Grade 2: Mild gait impairment. Grade 3: Difficulty in walking which is not so severe as to require someone else's help to walk. Grade 4: Able to walk only with someone else's help or with the aid of a frame. Grade 5: Chairbound or bedridden.)

cord itself yields a better defined potential of greater amplitude with fewer technical problems than is obtained by less invasive recording techniques. In most of the invasive techniques previously described, recording of the SCEPs is made by placing the active electrode not ventral but dorsal to the spinal cord such as in the spinous processes,¹⁶ the interspinous ligament,¹⁷ the ligamentum flavum,^{10,18} or the dorsal epidural space.^{9,19,20} However, recording from the discs which are exposed during anterior surgery is more practical when the SCEP is used as a clinical test for clarifying the intervertebral level which requires an anterior decompression.

In this series of patients whose paresis was so severe that walking aids were necessary preoperatively, the SCEPs consistently revealed the spinal conduction block.

The SCEPs recorded with this technique were probably derived from sensory ascending pathways.¹⁹ Nonetheless, the SCEPs formed a good representation of the entire spinal cord function, since not only sensory disturbance but also motor deficit showed marked improvement following the operation at a single level which was identified with the aid of SCEPs. Although the specified levels were closely related to the spinal cord compression demonstrated by MRI, significant cord compression seen at other levels on MRI turned out to be asymptomatic on many occasions. This is in agreement with a previous study.⁶ Thus, in many

patients with CSM, decompression over a number of motion segments would be superfluous.

The spinal conduction block demonstrated in the present study is more likely to be explained by local ischaemia of the spinal cord at the site of compression^{1,15} rather than demyelination,^{15,21} since neurological improvement was usually apparent as early as the first postoperative week. A short duration of symptoms before the operation, with an average of 4.5 months (range 1–9) was considered to have an important bearing in the satisfactory functional recovery despite the severity of the preoperative incapacity. In every patient the neurological symptoms had deteriorated quite rapidly, leading to prompt referral and then to relatively early operative intervention before major axonal destruction developed. Many of the patients included in this series were of an advanced age, with an average age of 72 years (range 58–81). It appears that elderly patients tend to be seriously disabled with some critical damage to long tracts of the spinal cord, but such patients are also expected to be able to restore their neurological capacity²² with appropriate management.

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