Classification of cervical spondylosis or disc protrusion by preoperative evoked spinal electrogram

Follow-up study

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The evoked spinal electrogram (SEG) was studied in 11 patients with cervical spondylotic myelopathy or disc protrusion. All the patients were severely handicapped before surgery. The evoked SEG was classified in three grades before and during surgery. Periodic follow-up studies were done at 18 to 35 months, with an average of 24 months. Four of six patients with normal or slightly abnormal SEG recordings showed satisfactory improvement of the disability; however, only one patient showed any improvement when the recording was moderately or severely abnormal. Location of the cord lesion and type of surgery were similar in all patients examined, and the difference was likely ascribed to the physiological change of the intramedullary structures. The evoked SEG provides some information relative to the surgical treatment of spondylotic myelopathy or disc protrusion with cord lesion.

Key Words: evoked potential • spinal cord compression • dorsal roots • spinal electrogram • cervical spondylosis

Since Gasser and Graham10 reported their pioneer work in 1933 on electropotentials produced in the spinal cord by stimulation of dorsal roots, there has been a good number of neurophysiological studies of spinal electrophysiology and its clinical application.15 Most of the recent papers, however, have been concerned with the prognostic significance of the spinal electrogram in acute spinal cord injury.7,18 We have studied preoperative evoked spinal electrograms (SEG) in 11 patients with cervical spondylotic myelopathy or disc protrusion in relation to the immediate and long-term postoperative results. The diagnostic value of the evoked SEG in cervical myelopathy has still to be proved; nevertheless, an interesting correlation was observed between the abnormality of the evoked SEG and the functional recovery of the cord lesion in most of our cases.

Clinical Material and Methods

Our series consisted of 11 cases. Nine patients with cervical spondylotic myelopathy...
Preoperative clinical classification in 11 patients

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Lesion Level</th>
<th>Type of Surgery</th>
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</tr>
<tr>
<td>1</td>
<td>68</td>
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<td>motor system</td>
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<td>transverse lesion</td>
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<td>C5–7</td>
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<td>brachialgia and cord</td>
</tr>
<tr>
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<td>40</td>
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</tr>
<tr>
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<td>central cord</td>
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<td>disc protrusion</td>
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<td>transverse lesion</td>
</tr>
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<td>C6–7</td>
<td>discectomy</td>
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<td>transverse lesion</td>
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were aged between 40 and 68 years; five were male and four female. All nine patients with cervical spondylotic myelopathy were operated on from the posterior approach, with sufficiently extensive laminectomy and foraminotomy as described by Stoops and King.22 None of the patients received dural incision or graft. Two patients with cervical disc protrusion underwent discectomy via the anterior approach of Cloward.4 Both of these patients were in their fifth decade.

Neurological examination of each patient was made periodically and the duration of the follow-up study ranged between 18 and 35 months, with an average of 2 years. The disability of the patients was evaluated,1,14,22 and the patients were classified into four disability groups as follows: Group 1: mild disability, living a normal daily life and able for full-time work; Group 2: moderate disability, appreciably handicapped in everyday tasks and able for only part-time work; Group 3: severe disability, not bedridden, and able to carry on an indoor life; Group 4: severe disability, confined to bed. All of our patients were in disability Group 3 or 4 preoperatively (Table 1). The spinal cord lesion was analyzed pre- and postoperatively into one of five categories in each patient as described by Crandall and Batzdorf:4 transverse lesion syndrome; motor system syndrome; central cord syndrome; Brown-Séquard syndrome; brachialgia and cord syndrome.

Chloride-silver needle electrodes were introduced into the epidural space by the method described previously by Shimoji, et al.,18 this method is identical to that of epidural anesthesia customarily applied in surgery. The evoked SEG was monitored by stainless steel wires, 150 µ in diameter, placed in the epidural space of the affected cervical segments and in the space 1 or 2 segments above. The wires were insulated from the tip up to 5 mm. The indifferent needle electrode was inserted into the supraspinous ligament of the adjacent segment to minimize interference from other sources. The accurate position of the electrodes was confirmed by x-ray film. For preoperative recording, square pulses of 0.5 msec duration and of varying intensities were delivered every 1 to 2 seconds by the needle electrodes through a stimulator to the ulnar or the median nerve at the elbow. The SEG was attached to a polygraph and 100 responses were averaged with a computer. Time constant applied was 0.3 sec for recording.

We also recorded evoked SEG from the exposed dura during surgery with the patients under neuroleptanaesthesia with fentanyl citrate (0.005 to 0.008 mg/kg), droperidol (0.4 mg/kg) and 50% N2O. The indifferent needle electrode was placed on the supraspinous ligament or other non-neural tissue. Intraoperative recording was found better than preoperative epidural recording and constant results were obtained without untoward effects. As Hughes and Gasser13 reported in an experimental work, the distance between the electrode and the posterior
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root showed a strong influence not only to the amplitude but to the pattern of the SEG and preoperative epidural placement of the electrodes was not always satisfactory. It was most important to reconfirm the abnormal preoperative pattern by the recording during surgery. Postoperative recording of the evoked SEG was not made in any patient because of the technical difficulty of performing an epidural puncture on the laminectomy-mized neck and postoperative change of the evoked SEG could not be followed.

Results

Normal SEG Patterns

The normal pattern of the evoked SEG, directly activated by somatosensory stimulus to the spinal segments tested, has been reported previously. Two of our patients had normal evoked SEG's (Cases 1 and 10). The SEG evoked by electrical stimulation of the corresponding segmental nerves essentially consisted of three early components followed by delayed waves. The early components were successive positive, negative, and positive deflections referred to as P1, N1, and P2. The peak latency, amplitude, and duration of these early components were almost constant in the same stimulus condition, except for P2 which showed some variability (Fig. 1). The wave forms of the delayed components varied from time to time during the course of stimulation. However, negative and positive deflections named N2, P3, N3, P4 were most frequently noticed following the early components. The early triphasic complex showed almost the same pattern in the spinal segment directly activated regardless of whether the electrodes were ipsi- or contralateral. Also it was found that the cervical segments are the best site for recording SEG without other electrical interference.

Fig. 1. Normal pattern of the evoked SEG recorded from the epidural space of C-5 in response to ulnar nerve stimulation.

The SEG recorded with the electrodes positioned at the anterior surface of the dura prior to anterior discectomy showed totally inverted polarity of N1 to P2 complex against the posterior epidural recordings, and the delayed components were obscure.

Abnormal SEG Patterns

The nine remaining patients showed abnormal patterns of evoked SEG, and were graded as follows: SEG Grade 1: slightly abnormal, P1 and N1 waves were well recorded, whereas the P2 wave was absent; SEG Grade 2: moderately abnormal, the N1 wave was still visible although diminished in amplitude, and the discharge that followed including P2 was totally flat; SEG Grade 3: severely abnormal, only the initial spike discharge was recorded and the N1 to P2 complex disappeared. Figure 2 shows actual recordings of abnormal patterns and their schematic classification. In all recordings of the present study P1 wave was preserved and well identified.

Results of Follow-Up Study in Relation to Evoked SEG

Neurological evaluation of the patients before and after surgery, and the results of the follow-up study are summarized in Table 2. Normal SEG Patients. Almost normal recording of the evoked SEG was obtained from two patients (Cases 1 and 10). One patient failed to show functional recovery, whereas the other patient had only limited improvement and could only work part-time. Follow-up study of these two patients suggested that the reason for the poor result in spite of normal SEG recording was due in one case to a dissociated complication and in the other to faulty recording. In Case 1, that of a 68-year-old farmer, the cervical spine film revealed marked spondylotic change at C-5, C-6 and C-7, and partial obstruction of a myelogram. This patient also had a degenerative cerebral lesion, accompanied by disorientation and loss of memory. Preoperative pneumoencephalogram disclosed moderate ventricular dilatation. The evoked SEG of this patient indicated that the motor difficulty was not attributed to the segmental lesion of the cervical cord. In Case 10, the
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Fig. 2. Actual recordings of the abnormal evoked SEG's (left) and their schematic classification (right). Top: Slightly abnormal recording in Case 5, obtained from the level of C-6 and C-7. Second: Moderately abnormal recording in Case 7 at C-5 and C-6. Third: Severely abnormal recording in Case 8 at C-4 and C-5, which showed only initial spike discharge (upper), whereas the recording obtained simultaneously from the level two segments below at C-7 showed prominent N1 (lower). Fourth: Calibration, 0.5 μV and 100 msec in analysis time.

electrodes were placed in the anterior surface of the dura through a burr hole between C-5 and C-6, and the segment of the cord affected by cervical disc protrusion might have been above or below the level tested.

SEG Grade 1 Patients. Grade 1 evoked SEG was obtained from four patients (Cases 3, 5, 9 and 11). Cases 3 and 5 showed immediate improvement from disability Group 3 to 2, and both patients were working full-time when examined 15 months and 34 months after surgery. The other two patients (Cases 9 and 11) remained in disability Group 3 at the time of discharge; however, they were able to do part-time work 18 months after surgery. Table 2 lists the type of syndrome observed pre- and postoperatively.

SEG Grade 2 Patients. Grade 2 evoked SEG was obtained from three patients (Cases 4, 6 and 7). The group of disability of these three patients did not change their disability group during follow-up 19 to 34 months postoperatively, and they were able to do only limited activity besides taking care of themselves. Two patients with brachialgia and cord syndrome had no change and the third changed from transverse lesion to motor system syndrome (Table 2).

SEG Grade 3 Patients. Grade 3 evoked SEG was recorded from two patients (Cases 2 and 8). Case 2 showed the most abnormal evoked SEG with an almost flat N1 to P2 complex; the patient stayed in the same disability Group 4. Case 8 showed gradual improvement of motor function and became able to assume part-time work 20 months after surgery. The type of lesion in this patient was brachialgia and cord syndrome, and multiple cervical roots were involved. This could account for the potentials being severely abnormal in this case, in which there was a little improvement.
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**TABLE 2**

Degree of disability on follow-up study in relation to the evoked SEG*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>SEG Grade</th>
<th>Disability Group</th>
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*Numbers in parentheses indicate the postoperative months at the follow-up study. Type of spinal cord syndrome: M = motor system syndrome; T = transverse lesion syndrome; B & C = brachialgia and cord syndrome; B - S = Brown-Séquard syndrome; and Cent = central cord syndrome.

**Discussion**

All patients were in disability Group 3 or 4 at the preoperative evaluation. Improvement of the physical disability from Group 3 to 1 at the end of the follow-up study was observed in two patients whose evoked SEG was Grade 1. Two out of four SEG Grade 1 patients were still moderately disabled although they were able to keep working at a bicycle shop and as a farmer. Among five patients with SEG Grade 2 or 3 only one was able to resume part-time work; the other four patients remained in the same disability group as preoperatively. Yet, one of the two patients with normal evoked SEG also failed to show improvement. The diagnostic value of the evoked SEG is still tentative; however, it does suggest that the patient with slightly abnormal evoked SEG has a good chance of functional recovery, whereas moderately and severely abnormal evoked SEG's indicate that a patient will stay in the same disability group with little improvement. On the contrary, if a normal SEG is obtained from a severely disabled patient, the recording might not be from the segment affected. Also, it is very difficult to judge the integrity of the spinal cord in the case of typical Brown-Séquard syndrome, because the root-cord potentials can be recorded on the ipsi- and contralateral sides to the stimulation. Shimoji, et al.,* have reported that the fundamental pattern of the evoked SEG recorded below the level of cord transection was similar to the normal pattern. We have previously reported the normal evoked SEG of a patient with olivopontocerebellar atrophy. The pattern of the evoked SEG was not related to the motor system lesion of the cord unless it was produced by a segmental lesion.

There are two types of evoked SEG, one obtained from the spinal segments directly activated by a somatosensory stimulus, that is the segmental SEG, and the other detected from more rostral segments, the conducted SEG. The recording of the conducted SEG and the somatosensory evoked potentials from the cerebral cortex should be a valuable diagnostic tool in detecting the functional block of the spinal pathways, however,
our experience has proved it difficult to locate the level of the cord lesion. In our present study, the segmental SEG was used to evaluate patients with cervical spondylotic myelopathy or disc protrusion; we attempted to estimate the seriousness of the segmental cord lesion by analyzing the early complex (P1, N1, and P2) of the evoked SEG.

It is generally agreed that the initial positive deflection (P1) is related to the arrival at the spinal cord of afferent volleys conducted by dorsal root fibers. The subsequent negative wave (N1) has been variously interpreted and its origin is ascribed to afferent terminals, interneurons, and/or neurons in the dorsal horn. Intramedullary evoked potentials were studied by Eccles, Sprague and Hongchien, and others utilizing micro-electrode techniques; they regarded the N1 waves as the postsynaptic potentials of the interneurons in the gray matter of the cord. Austin and McCouch suggested that the postsynaptic components of intermediary cord potential were also included. The P2 wave in an experimental work has been considered postsynaptic in origin and currently two hypotheses are supported; one is the primary afferent depolarization and the other is the depolarization potential of the motor neurons in the anterior horn. In reviewing the human evoked SEG, P1 corresponds to the initial spike potential in animal experiments and is accompanied occasionally by a small negative discharge (A) between P1 and N1, which is considered as the action potential of the dorsal root fibers. N1 is the negative intermediary and P2 the positive intermediary potentials as described before. The early complex of the human evoked SEG indicates that physiological function of the cord is referable to specific intramedullary structures, and is influenced by pathological processes such as ischemic change or compression.

Gelfan and Tarlov have demonstrated that the anoxic change induced by ischemia or asphyxia progressively modified the early complex potentials until each of the deflections was abolished. In an ischemic change the A wave and the initial spike potentials disappeared in the final stage of the experiment; however, they were first affected by a compressive lesion and the order of disappearance of the N1–P2 complex was the reverse of that seen in spinal ischemia. In our present study, the initial spike potential was preserved in all cases and the alteration of the N1–P2 complex predominated. We have been convinced that the abnormal pattern of the human evoked SEG obtained from patients with cervical spondylotic myelopathy or disc protrusion should be ascribed to the ischemic change of the cord rather than to cord compression. There seems to be an interesting correlation between the abnormal pattern of the evoked SEG and the results of surgery in most cases; however, study of a larger number of patients is needed before it can be determined whether this test will have any significant diagnostic value.

References
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