SUBCORTICAL AND CERVICAL SOMATOSENSORY EVOKED POTENTIALS IN CERVICAL SPONDYLOTIC MYELOPATHY

WAHIED LABIEB MOHAMMAD and ALAA MOHAMMAD AL-NAGGA

Rheumatology & Rehabilitation and Neurosurgery Departments, Alexandria University Faculty of Medicine

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ABSTRACT

Aim of Work: To determine whether the diagnostic yield of SEPs in cervical spondylotic myelopathy can be improved by assessing separately dorsal column and dorsal horn responses to stimulation of the median nerve in patients with cervical spondylotic myelopathy.

Material and Methods: The study was carried out on 20 patients with cervical spondylotic myelopathy and 20 healthy controls. Somatosensory evoked potentials to median nerve stimulation were studied. The following montages were used: Erb's point ipsilateral to stimulation, Erb's point contralateral to stimulation (N9), spinous process of 5th cervical vertebra, anterior cervical (N13), parietal scalp contralateral to stimulation, parietal scalp ipsilateral to stimulation (N20), parietal scalp contralateral to stimulation and shoulder contralateral to stimulation (P9, P14).

Results: Abnormal N13 potential, P14 and N20 was found in 17 (85 %), 10 (50 %) and 6 (30 %) of cases respectively. Thus normal N20 coexist with a abnormal P14 in four patients. Abnormalities of scalp and cervical SEPs, defined respectively as abnormal N20 or P14 on the one hand and abnormal N13 on the other were combined in three different patterns, and distributed as follows: 9 patients (45 %) had normal scalp SEPs with abnormal cervical responses; 8 patients (40 %) showed abnormalities of both scalp and cervical SEPs; in two patients (10 %) normal cervical responses were associated with abnormal
scalp SEPs on both sides. Thus, about half of the patients with an isolated abnormality of the cervical N13 response would have been considered as having normal upper limb SEPs if recorded with a conventional frontal montage, which does not allow a selective assessment of this variable. In nine patients there was an increased signal on T2-weighted MRI scans of the cord at the cervical level.

**Conclusions:** The cervical potential N13 and the subcortical potential P14 are reliable in diagnosing cervical spondylotic myelopathy. They are more frequently abnormal than the cortical N20 potential.

**INTRODUCTION**

Spondylotic changes of the cervical spine are the most common cause of cervical myelopathy or radiculopathy (Emery, 2001). The diagnosis of cervical spondylotic myelopathy (CSM) is based on the combination of signs suggesting involvement of long pathways (spastic paraparesis) and dysfunction of motor and sensory neurons in the cervical grey matter (Adams, 1976). Nevertheless, sensory motor and reflex changes in the upper limbs can be missing (Ferguson & Caplan, 1985) and, in the absence of sensory deficits, cervical spondylotic myelopathy can be confused with other degenerative diseases such as amyotrophic lateral sclerosis.

Minimal symptoms without hard evidence of gait disturbance or pathologic reflexes warrant non-operative treatment, but patients with demonstrable myelopathy and spinal cord compression are candidates for operative intervention (Emery 2001).

Magnetic resonance imaging (MRI) of the cord can show several types of signal abnormalities at the level of cord compression (Al-Mefty et al., 1988 and Mehalic, 1990). However, there is no correlation between the severity of MRI abnormalities and clinical presentation (Kanchiku et al., 2001; Berthier et al., 1996 and Miyoshi & Kimura, 1996). Therefore, it is clinically relevant to develop complementary investigations for assessing cord dysfunction at the cervical level.

Somatosensory evoked potentials (SEPs) have been used to disclose abnormalities of the ascending sensory pathways in cervical spondylotic myelopathy. Previous studies with cephalic reference montages showed that dorsal column dysfunction can be demonstrated in 43% to 60% of patients
with lower limb SEPs, 24% to 59% of patients with median nerve SEPs (El-Negamy & Sedgwick, 1979; Ganes, 1980; Yu & Jones, 1985; Veilleux & Daube, 1987 and Perlik & Fisher, 1987). Abnormal lower limb SEPs are, however, of no value for localizing the dysfunction at the cervical level. Noordhout et al. (1998) found that cortical somatosensory evoked potential, N20, can be normal in patients with CSM.

Non-cephalic reference recording of SEPs allows a separate analysis of the dorsal horn N13 response and of the P14 potential. P14 is a far-field potential generated subcortically in the lower brainstem (Mauguiere et al., 1999), the latency of which reflects the transit time of the ascending volley up to the lower brainstem level. Abnormalities of the N13 potential have been found in diseases affecting the central grey matter (Emerson & Pedley, 1986; Urasaki et al., 1988; Restuccia & Mauguiere, 1991; Mauguiere & Restuccia, 1991 and Ibanez et al., 1992) and in a selected population of patients with cervical spondylotic myelopathy but with normal sensation (Restuccia et al., 1992). Moreover, prolonged P14 latencies in relation to a conduction slowing in the dorsal columns were found in focal cervical cord lesions as well as in multiple sclerosis (Mauguiere & Ibanez, 1985; Yamada et al., 1986; Garcia-Larrea & Mauguiere, 1988 and Turano et al., 1991).

Aim Of The Work:

To determine whether the diagnostic yield of SEPs in cervical spondylotic myelopathy can be improved by assessing separately dorsal column and dorsal horn responses to stimulation of the median nerve in patients with cervical spondylotic myelopathy.

PATIENTS AND METHODS

Patients:

Twenty patients (mean age 56 (range 37-77) years; 15 males and 5 females) with cervical spondylosis confirmed by MRI were studied. All patients showed spastic weakness of the lower limbs, brisk lower limb tendon jerks, and a unilateral or bilateral Babinski sign. Mild weakness and wasting in the upper limbs or reduction or absence of at least one of the upper limb tendon reflexes was found in 10 patients (20 limbs). No patient complained of pain or paraesthesia in the upper limbs. Joint and touch sensation in the upper limbs was impaired in 9 patients (7 bilateral and 2 unilateral, total: 16 limbs). There was segmental pain impairment in the upper limbs of 7 (14 limbs) patients. In nine
patients there was an increased signal on T2-weighted MRI scans of the cord at the cervical level.

All patients had nerve conduction and concentric needle EMG examinations. Motor and sensory nerves conduction velocity studies were performed in the upper limb with standard techniques (Preston & Shapiro, 1998). EMG activity in upper limb muscles was considered abnormal when there were fibrillation potentials and positive sharp waves in two or more areas of the muscle under study. Upper limb nerve conduction velocities were within normal limits in all patients. Concentric needle examination showed abnormalities confined to upper limb muscles in 10 patients.

**SEP Recording Procedure**

For SEP recording, the patient layed down on a couch in a warm room. The procedures and montage of SEP recommended by the International Federation of Clinical Neurophysiology was used (Mauguiere et al., 1999). The median nerve was stimulated at the wrist. Stimuli (0.5 ms square pulses) were delivered at the rate of 5 Hz with surface stimulating electrodes (cathode proximal) at motor threshold intensity. The filter bandpass was 10-3000 Hz, the analysis time was 50 ms.

Samples with excess interference were automatically edited out of the average. Two averages of 500 trials each were obtained. The recording electrodes (impedance below 5 kohm) were placed at the ipsilateral Erb’s point (EPi), over the spinous process of the 5th cervical vertebra (Cv5) and at the parietal scalp regions contralateral to stimulation (Pc). The parietal electrodes were located 2 cm posterior to Cz and 7 cm lateral to the midline. These locations are designated as Pc and Pi (P: parietal, c: contralateral to stimulation, i: ipsilateral to stimulation). The Erb’s point electrode was referred to the contralateral Erb's point (EPc).

To get the subcortical P9 and P14, the parietal scalp electrode (Pc) was referred to the shoulder (Sh) contralateral to the stimulated side. To get the cortical N20, the parietal electrode (Pc) was referred to the ipsilateral parietal cortex (Pi). This is to cancel the widely distributed subcortical P9 and P14 potentials. For the recording of the cervical N13 potential, grid 1 of the amplifier was connected to the Cv5 electrode and grid 2 to an electrode located immediately above the thyroid cartilage. This electrode site is referred to in the figures as anterior cervical (AC).
The rationale for this Cv5 to AC montage is that it records the activity generated by the transverse dipolar source of the N13 potential with a maximal amplitude (Restuccia & Mauguiere, 1991; Mauguiere & Restuccia, 1991; Ibanez et al., 1992 and Turano et al., 1991). Also, it permits the selective assessment of the amplitude of the dorsal horn response as it does not record potentials generated above the foramen magnum and tends to cancel the N11 potential, which reflects the ascending volley in the dorsal columns (Desmedt & Cheron, 1980; Desmedt & Cheron, 1981; Anziska & Cracco, 1981 and Lueders et al., 1983) and is picked up by both Cv5 and AC electrodes (Desmedt & Cheron, 1980 and Desmedt & Cheron, 1981).

A stationary N9 potential, reflecting the positive front of the afferent volley in the cervical roots (Yamada et al., 1980) is also picked up by both Cv5 and AC electrodes and the wave form resulting from the algebraic subtraction of the larger AC P9 from the smaller Cv5 P9 is made of a small negative-positive diphasic deflection preceding the cervical N13 (Restuccia & Mauguiere, 1991).

**Normative Data:**

To match control subjects for age with patients with cervical spondylotic myelopathy we studied normal subjects over 40 years of age (20 subjects, age range 40-60, mean 52.7, 14 males and 6 females). For assessing the conduction time in somatosensory pathways, peak latencies of Erb's point N9, cervical N13, subcortical P9 and P14, and parietal N20 potentials were measured. To eliminate interindividual variations related to arm length, N9-N13, P9-P14, P14-N20, and P9-N20 interpeak intervals were also calculated.

The amplitude of the N13 potential was assessed by calculating the N13/P9 amplitude ratio using the Cv5-AC traces (Restuccia & Mauguiere, 1991; Mauguiere & Restuccia, 1991; Ibanez et al., 1992 and Restuccia et al., 1992). Table (1) shows the results of normal controls.

Table (1): Normal SPE data.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Limit of normal value (mean+3SD)</th>
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</thead>
<tbody>
<tr>
<td>N9</td>
<td>10.4 ms</td>
<td>0.75 ms</td>
<td>12.65 ms</td>
</tr>
<tr>
<td>N13</td>
<td>13.6 ms</td>
<td>0.72 ms</td>
<td>15.76 ms</td>
</tr>
<tr>
<td>N13/P9 amplitude (Cv5-AC)</td>
<td>0.6</td>
<td>0.2</td>
<td>1.2</td>
</tr>
<tr>
<td>P9</td>
<td>9.7 ms</td>
<td>0.8 ms</td>
<td>12.1 ms</td>
</tr>
</tbody>
</table>
RESULTS

Table (2): Distribution of clinical signs and SEP abnormalities.

<table>
<thead>
<tr>
<th>Clinical signs</th>
<th>Somatosensory response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abnormal N13 (32 limbs)</td>
</tr>
<tr>
<td>Lower motor neuron signs (20 limbs)</td>
<td>18/32</td>
</tr>
<tr>
<td>Hypoesthesia to Pain (14 limbs)</td>
<td>10/32</td>
</tr>
<tr>
<td>Joint and touch hypoesthesia (16 limbs)</td>
<td>13/32</td>
</tr>
<tr>
<td>Abnormal P14 (18 Limbs)</td>
<td>11/18</td>
</tr>
<tr>
<td>Lower motor neuron signs (20 limbs)</td>
<td>7/18</td>
</tr>
<tr>
<td>Hypoesthesia to Pain (14 limbs)</td>
<td>16/18</td>
</tr>
<tr>
<td>Joint and touch hypoesthesia (16 limbs)</td>
<td>5/10</td>
</tr>
<tr>
<td>Abnormal N20 (10 Limbs)</td>
<td>8/10</td>
</tr>
<tr>
<td>Lower motor neuron signs (20 limbs)</td>
<td>7/10</td>
</tr>
</tbody>
</table>

Abnormal SEPs was found in 19 patients (95%). In only one patient SEP abnormalities were limited to the right side. The latency of the N9 and P9 responses were always within normal limits, as well as the N9-N13 interpeak interval and the N13 latency. Abnormalities in N20 potential were always associated with an abnormal P14 potential.

N13 Abnormalities

Abnormal N13 potential (Low amplitude and/or low N13/P9 ratio) was found in 17 (85%) patients (Bilateral in 15 patients and unilateral in two, total 32/40 limbs). A normal N13 was found in three patients. Table 2 shows the distribution of N13 findings and clinical signs in the corresponding upper limb.
P14 Abnormalities

The P14 potential was delayed in 10 (50%) cases (bilateral in 8, unilateral in 2, total 18/40 limbs). Normal P14 potentials were found in 22/40 upper limbs (55%). Table (2) shows the distribution of P14 findings and clinical signs in the corresponding upper limb.

Fig. (1a): Delayed P14 with normal latency of N20 after stimulation of median nerve: The peak latency of N9 and P9 are within normal limits. The N13 latency and amplitude are normal, N20 latency and P9-N20 are within normal limits, and the P9-P14 interpeak latency is increased. Epi-Epc: Erb's point ipsilateral to stimulation-Erb's point contralateral to stimulation. Cv5-AC: spinous process of 5\textsuperscript{th} cervical vertebra- anterior neck above thyroid cartilage. Pc-Sh: parietal scalp contralateral to stimulation-shoulder contralateral to stimulation. Pc-Pi: parietal scalp contralateral to stimulation-parietal scalp ipsilateral to stimulation.
Fig. (1b): MRI of Cervical cord. (T2-weighted). showed stenosis of cervical cord with spondylotic cord compression at C4-C5, C5-C6 and C6-7 level.

N20 Abnormalities

N20 potential was delayed in 6 (30%) cases (four bilateral and 2 unilateral, total 10/40 limbs). Table (2) gives the distribution of N20 findings and clinical signs in the corresponding upper limb. The N20 potential was normal in 14 cases. Thus a normal N20 coexisted with a clearly abnormal P14 in four patients. Fig. (1) illustrates this pattern.

Combinations of scalp and spinal SEPs abnormalities:

Abnormalities of scalp and cervical SEPs, defined respectively as abnormal N20 or P14 on the one hand and abnormal N13 on the other were
combined in three different patterns, and distributed as follows: 9 patients (45 %), 7 bilateral and 2 unilateral, had normal scalp SEPs with abnormal cervical responses (16/40 limbs, fig. 2); 8 patients (40 %) showed abnormalities of both scalp and spinal SEPs; in 2 patient (10 %) normal segmental spinal responses were associated with abnormal scalp SEPs on both sides.

Thus, about half of the patients with an isolated amplitude abnormality of the cervical N13 response would have been considered as having normal upper limb SEPs if recorded with a conventional frontal montage, which does not allow a selective assessment of this variable (Mauguiere & Restuccia, 1991).

Clinical Correlations (Table 3):

Abnormal P14 and N20 were significantly correlated with loss or reduced joint and touch sensation ($X^2$, $p < 0.05$), but neither with segmental pain hyposthesia, nor with absent or reduced tendon reflexes in the corresponding upper limb. Abnormal N13 was correlated with absent or reduced tendon reflexes in the corresponding upper limb ($X^2$, $p < 0.05$), but neither with segmental pain hyposthesia, nor with lost or reduced joint and touch sensation.

Fig. (2a): Association of normal scalp SEPs and abnormal spinal SEP. The
peak latency of N9, P9, P14 and N20 responses as well as P9-P14 and P14-N20 are within normal limits. N13 potential was abnormal. Abbreviations are the same like figure (1).

Fig. (2b): MRI of cervical cord (T1- and T2 weighted) showed stenosis of the cervical canal with compression at C4-C5

**DISCUSSION**

It is shown that the recording of both spinal and scalp SEPs in patients with cervical spondylotic myelopathy can reveal two main types of cord dysfunction at the cervical level.

The most frequent SEP abnormality was the reduction of the cervical N13 potential (in 85 % of cases). This abnormality was often associated with
normal scalp SEPs, abnormal N13 with normal P14 and N20 potentials having been found in 9 cases. A loss of N13 with normal P14 and N20 potentials is known to occur in lesions of the cervical grey matter leaving dorsal columns unaffected (Hayashida et al. 2000), such as cervical syrinxes (Emerson & Pedley, 1986; Urasaki et al., 1988; Restuccia & Mauguiere, 1991 and Mauguiere & Restuccia, 1991) and intramedullary tumours (Ibanez et al., 1992).

Table 3: Correlation between clinical signs and SEP abnormalities.

<table>
<thead>
<tr>
<th>No. of Limbs</th>
<th>Tendon reflex</th>
<th>Pain</th>
<th>Joint sensation</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>normal 20</td>
<td>normal 26</td>
<td>normal 24</td>
</tr>
<tr>
<td>Normal N13</td>
<td>8</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Abnormal</td>
<td>12</td>
<td>20*</td>
<td>21</td>
</tr>
<tr>
<td>P14 22</td>
<td>12</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>Abnormal</td>
<td>8</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>N20 30</td>
<td>16</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Abnormal</td>
<td>4</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

* p<0.05

Therefore, the isolated abnormality of the N13 potential in patients with cervical spondylotic myelopathy is thought to reflect an anatomical damage limited to the cervical grey matter. It is proposed that this finding could reflect a decreased blood supply to cervical cord from anterior spinal artery (Restuccia et al. 1992). The reason for our high rate of N13 abnormalities, compared to the lower detection rates of upper limb SEPs in earlier studies (El-Negamy & Sedgwick, 1979; Ganes, 1980; Yu & Jones, 1985; Veilleux & Daube, 1987 and Perlik & Fisher, 1987) is the use of the neck to anterior cervical montage instead of the neck to forehead montage for the recording of the N13 potential.

The cervical response recorded with the last montage is an amalgam of the cervical N13 and scalp P14 potentials (Mauguiere & Ibanez, 1985). P14 is not significantly affected by selective lesions of the cervical grey matter.
Subcortical & Cervical SEP in Cervical Spon. Myelopathy  Mahammad & Naggar


Even though correlations between clinical signs and N13 abnormalities are not simple, abnormalities of the N13 potential are strongly related to the compression level as revealed by MRI investigations. In three patients showing a normal N13 response, the cord compression was located at the C2-C3 level. A similar finding was previously reported (Fujimoto et al., 2001). On the other hand, abnormal SEPs were found in 50% of asymptomatic cases that showed abnormal MRI data and were clinically free (Bednarik et al., 1998). Restuccia et al. (1996) found that SEP is often more effective than clinical examination in revealing cord dysfunction.

Electromyographic signs of denervation in upper limb muscles were present in half of the patients. Although we could not exclude a radicular damage, it seems more likely that this finding was due to the involvement of the anterior horn cells. The patients in fact always presented a clear involvement of the spinal long tracts without radicular pain or paresthesiae.

Another frequent SEP feature in the study was the abnormality of the subcortical P14 potential, which was found in 50% of cases. It is generally agreed upon that the P14 scalp far-field potential is generated subcortically in the brainstem in the ascending lemniscal pathways close to the cervicomedullary junction (Mauguiere, 1999; Mauguiere & Ibanez, 1985; Yamada et al., 1986; Garcia-Larrea & Mauguiere, 1988 and Turano et al., 1991). Thus, increased P9 - P14 interval directly reflects time dispersion of the ascending volley in the dorsal columns at the cervical level.

In earlier studies, where a cephalic reference montage was used, scalp SEP abnormalities in cervical spondylotic myelopathy were constantly represented by the abolition or latency delay of the parietal N20 response. The evaluation of abnormal dorsal column function provided by a prolonged N20 latency or N13-N20 interval is indirect and includes the transit times in medial lemniscus and thalamocortical fibers. Therefore, any intracranial conduction slowing in the somatosensory pathways can cause an N20 abnormality. The study showed two evidences that evaluation of the subcortical P14 far-field provides more reliable information on dorsal column dysfunction than that of the parietal N20 potential. Firstly, a greater percentage of abnormalities for
P14 than for N20 was found. In four patients, N20 was still recognizable and of normal latency, whereas the P14 was delayed (Fig. 2). The latency delay of the P14 potential with a normal N20 can be explained by the resynchronization of the ascending volley in the intracranial somatosensory pathways (Hayashida et al., 2000). Secondly, by contrast with what has been seen for the N20 potential by Yu UL and Jones SJ (1985), a normal P14 after stimulation of an upper limb presenting with lost or reduced joint and touch sensation was never encountered.

An increased signal of spinal cord was found in 9 cases (45 %), whereas an abnormal SEP was found in 95 % of cases. Kanchiku et al. (2001) found abnormal SEPs in cases of cervical spondylotic myelopathy whose MRI did not show abnormal signal intensity or cord narrowing. Tsiptsios et al. (2001) stated that SEP is the most sensitive diagnostic investigation in cervical spondylotic myelopathy.

Conclusion:

It can be concluded that SEP measurement is a very sensitive test in diagnosing cervical spondylotic myelopathy.

REFERENCES


705


الجهاز المثار التحت قشرى والعنقى في اعتلال الحبل الشوكي الفقاري

وحيد لبيب محمد و علاء محمد التجار
قسم الروماتزم و التأهيل و جراحة الأعصاب، كلية طب جامعة الإسكندرية

الغرض: لتحديد إذا كان النتائج التشخيصي للجهاز المثار الحسسي في اعتلال الحبل الشوكي العنقى الفقاري يمكن تحسين استجابة العضود الخلفي واستجابة القرن الخلفي كل على حدة.

الطريقة: أجريت الدراسة على 20 مريضاً بعانون من اعتلال الحبل الشوكي العنقى الفقاري، و20 من الأصحاء. وتم تتبيل العصب الأوسط للحصول على الجهاز المثار الحسسي، وتم وضع القطب المسجل عند نقطة إريس والتنوء الشوكي للقشرة العنقية الخامسة وفرقة الرأس الجدارية.

النتائج: كان جهد إن 13، بي 14 و إن 20 غير طبيعي من 17 (85%) و 0 (50%) من الحالات على التوالي - وهذا يدل على أن الجهاز المثار بي 14 كان شاذًا في الإيجاب.

حالات كان الجهاز المثار إن 20 فقاعة طبيعي.

وكان هناك ثلاثة أنماط لتشذوب الجهاز المثار الحسسي العنقى والجهاز المثار الحسسي.

الحصصي بفروة الرأس: 9 مرضى (45%) كان الجهاز العنقى بفروة الرأس طبيعي مع جهد عنقي غير طبيعي، 8 مرضى (40%) كان الجهاز الالمانيين غير طبيعيين وفي أثناء من المرضى (10%) كان الجهاز العنقى طبيعي مع وجود جهد فروة الرأس غير طبيعي. هذا فأن حوالي نصف المرضى أظهروا تخزياً فقط في الجهاز العنقى إن 13 - وكأنوا سيتبرعون أن لهم جهد مثار حسسي طبيعي لو تم دراستهم فقط بالتنسق الجبهي المعتاد، والذي لا يسمح بالتنسق الانتقائي لذلك المتغير.

الاستنتاج: الجهاز العنقى إن 13 والتحت قشرى بي 14 يمكن عليهم في تشخيص اعتلال الحبل الشوكي العنقى الفقاري. وهم أكثر تغيرا من الجهاز القشرى إن 20.