THE RESULTS AND CONTRIBUTION OF ELECTROPHYSIOLOGICAL EXAMINATION IN PATIENTS WITH LUMBAR SPINAL STENOSIS

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ABSTRACT

Monoradicular or polyradicular lumbosacral involvement is typical of lumbar spinal stenosis. Needle electrode examination is considered the most useful procedure for the evaluation of patients with suspected radiculopathy. The clinical relevance of motor and somatosensory evoked potentials is, however, uncertain.

The aim of this study was to evaluate the results of electrophysiological tests in patients with lumbar spinal stenosis and to assess the contribution of electrophysiological tests made to diagnosis.

The study group consisted of 102 patients (44 males, 58 females, aged 62 +/- 13 years) with clinically symptomatic lumbar spinal stenosis documented by computed tomography scan, all of whom volunteered to participate in the study. All patients underwent electrophysiological examination, which included needle electromyography and nerve conduction studies of the lower extremities, somatosensory evoked potentials of tibial, sural and superficial sensory peroneal nerves, and motor evoked potentials to the abductor hallucis muscle and the tibialis anterior muscle.

On the basis of nerve conduction studies and needle electromyography, the presence of radiculopathy was established in 70.6% of patients with lumbar spinal stenosis; polyradicular involvement (46.1% of the patients) was more common than monoradicular involvement (24.5% of the patients). Involvement of the L4 root was established in 37.2% of the patients, L5 root in 51.9%, and S1 root in 50.9% of the patients. Abnormal motor evoked potentials were found in 30.7% of the patients and abnormal somatosensory evoked potentials in 58.8% of the patients with lumbar spinal stenosis. Normal needle electromyography and nerve conduction studies were recorded in 18.6% of the patients. When abnormalities of any evoked potentials were considered, the number of patients with normal electrophysiological findings was reduced to 12.7%.

Nerve conduction studies and needle electromyography are the most useful electrophysiological examinations for the...
evaluation of suspected radiculopathies in patients with lumbar spinal stenosis. Involvement of L5 and S1 roots is the most common. The diagnostic contribution of evoked potentials is of limited value in patients with lumbar spinal stenosis.

**ABBREVIATIONS USED**

LSS – lumbar spinal stenosis  
NC – neurogenic claudication  
MEP – motor evoked potential  
SEP – somatosensory evoked potential  
CT – computed tomography  
SD – standard deviation  
CMAP – compound muscle action potential  
CMCT – central motor conduction time  
MUAP – motor unit action potential  
SNAP – sensory nerve action potential  
EMG – electromyography  
NCS – nerve conduction study  
AH muscle – abductor hallucis muscle  
TA muscle – tibialis anterior muscle

**INTRODUCTION**

Lumbar spinal stenosis is defined as any type of narrowing of the spinal canal, nerve root canals, or intervertebral foramina [1]. In the pathogenesis of LSS, the degenerative process in the lumbar spine is the main component producing compression of neural tissue in the spinal and/or nerve root canal [2]. LSS can give rise to several clinical syndromes: neurogenic claudication, low back pain and/or radiculopathy, and chronic cauda equina syndrome. Postural dependency is a hallmark of the symptoms of LSS. Spinal extension narrows the spinal canal and exacerbates symptoms, whereas spinal flexion increases the dimensions of the spinal canal and reduces symptoms [3, 4, 5]. NC is typical of LSS and is characterised by intermittent pain and paresthesia of the leg(s), most often in a lumbosacral root distribution, followed by weakness apparent on walking or standing [6, 7]. The incidence of NC is reported at 11 %–100 % in patients with LSS; the mean calculated from 32 studies is 62 %. LSS is currently the most common diagnosis for individuals over the age of 65 undergoing spinal surgery [8].

The diagnosis of LSS is based on the results of clinical examination and radiological documentation of narrowing of the lumbar spinal canal [9, 10]. Whereas clinical examination, even in severe LSS, has shown no specific sensory-motor deficit, electrophysiological recordings have indicated a neurogenic disorder within the lumbar spine of a majority of the patients. Electrophysiological recordings thus supplement neurological examination when the clinical relevance of a radiologically suspected LSS needs to be confirmed [11].

Electrophysiological examination in LSS is intended to detect lumbosacral root involvement (radiculopathy). EMG, especially needle electrode examination, is considered the most useful procedure in the detection of radiculopathy. Nerve conduction studies may yield abnormal results only rarely in radiculopathies, but are essential to the elimination of other conditions that may produce similar symptoms and signs [12]. Further, examination of SEPs and MEPs is used in different degree, but consensus on the contribution of evoked potentials in the diagnostics of LSS has not been established and the clinical relevance of MEPS and SEPs is uncertain [13]. Initially, the contribution of evoked potentials to the diagnostics of radiculopathy was overestimated. Electrophysiological examination in LSS patients is also used to exclude other peripheral neurogenic lesions (for example diabetic polyneuropathy). The clinical differentiation between lumbosacral polyradicular disease (typical of LSS) and generalised peripheral neuropathies of the distal-axonal type (typical of diabetic patients) can sometimes be difficult [14]. Electrodiagnostic testing is quite specific and reasonably sensitive in diagnosing spinal stenosis in comparison with low back pain or asymptomatic persons, and can detect neuromuscular diseases mimicking stenosis [15].

EMG findings may vary in patients with LSS. The most frequent finding (approximately 50 % of the patients) is bilateral multiple lumbosacral radiculopathy (cauda equina lesion). Polyradicular lumbosacral lesions are often asymmetrical, and usually involve the lower lumbosacral roots, especially S1. Chronic neurogenic MUAP changes tend to be prominent in needle EMG, whereas fibrillation potentials are often restricted to the more distal muscles of the myotomes. In some, two distinct lumbosacral radiculopathies occur either symmetrically or asymmetrically. In others, an isolated radiculopathy, almost always either an L5 or an S1 lesion, is found. Non-diagnostic abnormalities are encountered in some patients. Bilaterally absent H waves associated with normal sural SNAPs and a normal needle EMG of the lower extremities are common. Fibrillation potentials in a single limb muscle, most often one innervated by the S1 root, are sometimes encountered. In the remaining patients, extensive EMG examination is normal [16].

Magnetic transcranial and spinal stimulation of the motor pathway is a painless and safe neurophysiological technique for the examination of the central and proximal peripheral motor pathways [17]. Transcranial brain stimulation and paravertebral magnetic root stimulation are reliable diagnostic methods for the investigation of patients with radiculopathies. Their advantage is that disturbances of the motor functions in the nerve roots can be detected and, because of the different MEP patterns, localisation of the compression can often be established [18]. The clinical relevance of this examination is uncertain. False negative findings in MEP
The aim of the study was to evaluate the results of electrophysiological examination in patients with LSS and to assess the contribution of electrophysiological tests made to diagnosis.

MATERIALS AND METHODS

Patients with LSS

One hundred and two patients (44 males, 58 females, aged 62 +/- 13 years) were recruited consecutively from a total of 132 patients with LSS treated and observed in the Department of Neurology, Faculty Hospital, Brno, between 1998 and 2001. Inclusion criteria for patients with LSS may be as high as 65% [19, 20]. In contrast, altered tibial SEPs were observed in 61.5% of patients with LSS in another study [21].

The aim of the study was to evaluate the results of electrophysiological tests in patients with LSS and to assess the contribution of electrophysiological tests made to diagnosis.

Electrophysiological examination

All patients underwent electrophysiological examination, which included:

- Needle electromyography and nerve conduction studies of the lower extremities (Table 1). Needle EMG centred on the muscles of L4, L5, S1 myotomes bilaterally, with evaluation of abnormal spontaneous activity and analysis of action potentials of motor units. A conventional EMG device was used to perform the nerve conduction studies from temperature-checked skin. Motor conduction studies of the peroneal nerve (muscle responses recorded via surface electrodes placed over the extensor digitorum brevis muscle) and the tibial nerve (muscle responses recorded via surface electrodes placed over the abductor hallucis muscle) were performed bilaterally. Sensory conduction studies of the sural and superficial peroneal nerves were carried out employing an antidromic surface technique. The F-wave responses of the tibial and peroneal nerves and the H-reflex of the soleus muscle were recorded bilaterally. Submaximal stimuli with increasing voltage were delivered and facilitation was used to provide the maximum H-reflex amplitude.

- Somatosensory evoked potentials of tibial, sural, and superficial sensory peroneal nerves. Electrical stimulation of the tibial nerve was applied posterior to the medial ankle, the sural nerve was stimulated posterior to the lateral ankle, and the superficial peroneal nerve was stimulated in the join of both ankles at a distance of one third from the lateral ankle. Scalp registration was used in all examined nerves, while registration over the spinous process of vertebra L1 was used for the tibial nerve. The latency of potentials P40 and N45 and the amplitude of P40/N45 were evaluated in all examined nerves, while the latency of potential N22 was evaluated in the tibial nerve. Our electrophysiological laboratory has generated our own reference values for all the parameters, and latencies are correlated to body height. Prolongation of latencies of more than 3 SD above average, unelicited responses, side-to-side differences in latencies N22 or P40 of more than 3 SD above average, and reduction of amplitude P40/N45 of more than 3 SD below average (after logarithmic transformation) were considered abnormal.

- Motor evoked potentials to the abductor hallucis muscle and tibialis anterior muscle. A Magstim 200 was used for transcranial and spinal stimulation. In the course of spinal stimulation, the coil was located one centimetre to one side of the centre of the low lumbar spine; for transcranial stimulation, the coil was located above the motor cortex and facilitation was used. Supramaximal stimulation was applied. Spinal latency, cortical latency, CMCT, and amplitude of cortical response were determined. Unelicited responses upon transcranial and spinal stimulation, prolongation of latencies of more than 3 SD above average, and an amplitude of cortical response of less than six per cent of the amplitude of CMAP (our own reference values) were considered abnormal.

Radiological examination

The patients were radiologically examined according to the following protocol:

1. A plain radiograph of the lumbar spine was taken, with assessment for the presence of spondylarthrosis, scoliosis, and degenerative or isthmic spondylosis.
2. CT axial scans at three levels (L3-S1) were performed. The following standard parameters of the spinal canal were measured:
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Anteroposterior diameter of the spinal canal at the level of the middle of the L3, L4, and L5 vertebrae.

Transverse interarticular diameter (between ventral margins of facet joints) at the level of the upper margins of the L3/4, L4/5, and L5/S1 discs.

Lateral recess diameter bilaterally at the same levels as the transverse diameter.

CT criteria of spinal stenosis were based on our own normal data [22]:

- Central stenosis: anteroposterior diameter <11.7 mm and/or transverse diameter <16.0 mm
- Lateral stenosis: lateral recess diameter <5.2 mm

RESULTS

Nerve conduction studies and needle EMG

The presence of radiculopathy and/or polyneuropathy in patients with LSS was established on the basis of NCS and needle EMG. The criteria for radiculopathy included the presence of abnormal spontaneous activity or chronic neurogenic MUAP changes in two or more muscles that receive innervation from the same root, preferably via different peripheral nerves. Abnormal values for the soleus H-reflex amplitude were also used to assess S1 radiculopathy. If clinical suspicion of radiculopathy existed and needle EMG of the muscles of this myotome was normal but the H-reflex of the soleus muscle was abnormal, it was considered sufficient to confirm radiculopathy S1. If the H-reflex proved impossible to elicit, or a side-to-side difference in the amplitude of more than 50% in comparison with the healthy side emerged, the findings were considered abnormal. The criteria for polyneuropathy were non-elicitability or reduced amplitude in the sensory neurogram of the lower extremities, bilaterally abnormal values of the soleus H-reflex, and abnormal EMG needle findings in only the distal muscles of the lower extremities.

The presence of radiculopathy was established in 70.6% of the patients with LSS; polyradicular involvement (46.1% of the patients) was more common than monoradicular involvement (24.5% of the patients). Normal needle EMG and NCS were recorded in 18.6% of the LSS patients and polyneuropathy was established in 11.7% of the patients (Table 2).

The involvement of the particular roots was also established in patients with LSS (number of patients with radiculopathy in at least one lower extremity). Involvement of the L4 root emerged in 37.2% of the patients, L5 root in 51.9%, and S1 root in 50.9% (Table 3).

Evoked potentials (MEPs, SEPs)

Motor evoked potentials were evaluated in 101 patients with LSS (one patient was exempted from this examination because he had a pacemaker). Abnormal MEPs to the abductor hallucis muscle and/or to the tibialis anterior muscle were found in 31 patients (30.7%) (Table 4). On detailed analysis of MEPs it was found that prolongation of spinal latency or non-elicitability of spinal response to AH muscle and/or TA

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### Table 1

**Nerve conduction studies (NCS) of the lower extremities**

<table>
<thead>
<tr>
<th>Nerve conduction studies</th>
<th>Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor conduction studies</td>
<td>peroneal nerve tibial nerve</td>
</tr>
<tr>
<td>Sensory conduction studies</td>
<td>superficial peroneal nerve sural nerve</td>
</tr>
<tr>
<td>Late responses</td>
<td>F-wave of tibial nerve F-wave of peroneal nerve soleus H-reflex</td>
</tr>
</tbody>
</table>

### Table 2

**Evaluation of the nerve conduction studies and needle EMG**

<table>
<thead>
<tr>
<th>Type of involvement</th>
<th>Normal finding</th>
<th>Radiculopathy</th>
<th>Polyneuropathy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>monoradiculopathy</td>
<td>polyradiculopathy</td>
<td>together</td>
</tr>
<tr>
<td>Number of patients</td>
<td>19.0</td>
<td>25.0</td>
<td>47.0</td>
</tr>
<tr>
<td>In % of cases</td>
<td>18.6</td>
<td>24.5</td>
<td>46.1</td>
</tr>
</tbody>
</table>

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muscle had occurred in 27 patients. Three patients exhibited abnormal spinal response and an abnormal value of CMCT contemporaneously. One patient exhibited a low amplitude of cortical response in comparison with the CMAP amplitude. No isolated abnormality of CMCT to AH and/or TA muscle appeared. Contemporaneous abnormality of MEP to TA muscle and to AH muscle was found in 8 patients, only to TA muscle in 13 patients, and only to AH muscle in 10 patients. Abnormal SEPs were found in 60 patients with LSS (58.8 %) (abnormality of SEPs in at least one of the three nerves evaluated) (Table 5). Unambiguous damage to the peripheral part of the somatosensory pathway predominated. Abnormal SEPs of the tibial nerve in at least one lower extremity were found in 47.1 % of the patients, abnormal SEPs of the superficial sensory peroneal nerve in 35.3 %, and SEPs of the sural nerve in 39.2 %. Contemporaneous abnormality of all three types of SEP was found in 26 patients (25.5 %). Of 19 patients with normal EMG, one patient showed abnormal MEPs, 4 patients abnormal SEPs, and one patient abnormal SEPs as well as MEPs. When abnormalities of any evoked potential (MEP, SEP) were considered, the number of patients with normal electrophysiological findings was reduced from 18.6 % to 12.7 % (Figure 1).

DISCUSSION

It is believed that the presence of radicular or (possibly) polyradicular involvement is a typical electrophysiological finding in patients with LSS. In this study, the presence of radiculopathy was established in 70.6 % of the patients with LSS, with polyradicular involvement predominating (46.1 % of the patients). These results do not disagree with the literature. In a prior study, needle EMG and nerve conduction studies revealed pathology in 75 % of patients with LSS [23]. The most frequent findings in LSS patients are considered bilateral, multiple lumbosacral radiculopathies (in about 50 % of the patients), and in approximately 20 % of the patients the presence of monoradiculopathy is determined. Lower lumbosacral roots, especially L5 and S1, are afflicted most often in patients with LSS [16]. In a study involving 200 patients with lumbosacral radiculopathy, L5 radiculopathy was recorded in 47.6 % of the patients, S1 radiculopathy in 30 %,

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**Table 3**

<table>
<thead>
<tr>
<th>Distribution of radiculopathy</th>
<th>L₄</th>
<th>L₅</th>
<th>S₁</th>
<th>other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients with radiculopathy in at least one lower extremity</td>
<td>38.0</td>
<td>53.0</td>
<td>52.0</td>
<td>0.0</td>
</tr>
<tr>
<td>In % of cases</td>
<td>37.2</td>
<td>51.9</td>
<td>50.9</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Table 4**

<table>
<thead>
<tr>
<th>Type of MEP examination</th>
<th>MEP to AH muscle</th>
<th>MEP to TA muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients with abnormal MEP in at least one lower extremity</td>
<td>18.0</td>
<td>21.0</td>
</tr>
<tr>
<td>In % of cases</td>
<td>17.8</td>
<td>20.8</td>
</tr>
</tbody>
</table>

**Table 5**

<table>
<thead>
<tr>
<th>Type of SEP examination</th>
<th>SEP of tibial nerve</th>
<th>SEP of superficial sensory peroneal nerve</th>
<th>SEP of sural nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients with abnormal SEP in at least one lower extremity</td>
<td>48.0</td>
<td>36.0</td>
<td>40.0</td>
</tr>
<tr>
<td>In % of cases</td>
<td>47.1</td>
<td>35.3</td>
<td>39.2</td>
</tr>
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</table>
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and L4 radiculopathy in 17.2% [24]. This study found L5 radiculopathy in 51.9% of the patients and S1 radiculopathy in 50.9% of them; L4 root lesion was less common, in 37.2% of the patients. The higher percentage of the incidence of L4, L5 and S1 radiculopathy in this paper may be due to the selected patients with LSS, in whom the presence of multiple radiculopathy is supposed.

One patient was unsuitable for MEP examination because of a pacemaker. Abnormal MEPs to the AH muscle and/or to the TA muscle were found in 31 patients (30.7%). A study evaluating MEPs to the TA muscle in patients with LSS demonstrated abnormal findings in 42.3% of its subjects [21]. In our study, abnormal MEPs to the TA muscle (separately or in combination with abnormal MEPs to the AH muscle) were found in 20.8% of the patients. In another study, 65% of the patients (of 43 patients with LSS) exhibited abnormal MEPs (prolongation of central motor conduction time – CMCT) [25]. The incidence of abnormal MEPs in our study was substantially lower. The difference in the results may be partially explained by the fact that the latter study evaluated MEPs in three muscles in the lower extremity (quadriceps femoris muscle, TA muscle, and extensor digitorum brevis muscle) rather than our two, and that a “normal range” of latencies was defined as mean ± 2 SD (in our study mean ± 3 SD), thus increasing the probability of abnormal findings. Furthermore, the difference with the results of the study that demonstrated abnormal MEPs in 52.6% of the patients with acute radiculopathy is probably generated by different criteria for the definition of abnormal MEP findings (results that exceeded the mean ± 2 SD values were considered pathological and right/left difference amplitudes of more than 50% were also considered abnormal) [26]. When the MEP results in our study were analysed in detail, it was established that prolongation of spinal latency or non-elicitability of responses on spinal stimulation to AH muscle and/or to TA muscle (altogether 27 patients; i.e. 87% of abnormal MEPs) predominated among the abnormal findings, which is thought of as an indicator of lateral compression of the nerve root. This finding is possibly to be expected in patients with LSS because of the frequent presence of lateral stenosis. Three patients exhibited abnormal spinal responses and contemporaneous abnormal CMCT, which may possibly be interpreted as a combination of medial and lateral compression of the nerve root. No isolated abnormality of CMCT to the AH muscle and/or to the TA muscle (implying medial compression of the root) appeared. The results of the current study did not confirm those of Bischoff et al., which appeared to demonstrate that there are no major differences between MEPs and EMG in terms of their sensitivity in detecting nerve root compression [18]. In the current study, the sensitivity of EMG exceeded that of MEPs. The different results of our study and that of Bischoff et al. can be elucidated by the different inclusion criteria. Bischoff investigated patients with clinically symptomatic radiculopathy with frequent occurrence of muscle weakness and the correlation between muscle weakness and L4 radiculopathy in 17.2% [24]. This study found L5 radiculopathy in 51.9% of the patients and S1 radiculopathy in 50.9% of them; L4 root lesion was less common, in 37.2% of the patients. The higher percentage of the incidence of L4, L5 and S1 radiculopathy in this paper may be due to the selected patients with LSS, in whom the presence of multiple radiculopathy is supposed.

One patient was unsuitable for MEP examination because of a pacemaker. Abnormal MEPs to the AH muscle and/or to the TA muscle were found in 31 patients (30.7%). A study evaluating MEPs to the TA muscle in patients with LSS demonstrated abnormal findings in 42.3% of its subjects [21]. In our study, abnormal MEPs to the TA muscle (separately or in combination with abnormal MEPs to the AH muscle) were found in 20.8% of the patients. In another study, 65% of the patients (of 43 patients with LSS) exhibited abnormal MEPs (prolongation of central motor conduction time – CMCT) [25]. The incidence of abnormal MEPs in our study was substantially lower. The difference in the results may be partially explained by the fact that the latter study evaluated MEPs in three muscles in the lower extremity (quadriceps femoris muscle, TA muscle, and extensor digitorum brevis muscle) rather than our two, and that a “normal range” of latencies was defined as mean ± 2 SD (in our study mean ± 3 SD), thus increasing the probability of abnormal findings. Furthermore, the difference with the results of the study that demonstrated abnormal MEPs in 52.6% of the patients with acute radiculopathy is probably generated by different criteria for the definition of abnormal MEP findings (results that exceeded the mean ± 2 SD values were considered pathological and right/left difference amplitudes of more than 50% were also considered abnormal) [26]. When the MEP results in our study were analysed in detail, it was established that prolongation of spinal latency or non-elicitability of responses on spinal stimulation to AH muscle and/or to TA muscle (altogether 27 patients; i.e. 87% of abnormal MEPs) predominated among the abnormal findings, which is thought of as an indicator of lateral compression of the nerve root. This finding is possibly to be expected in patients with LSS because of the frequent presence of lateral stenosis. Three patients exhibited abnormal spinal responses and contemporaneous abnormal CMCT, which may possibly be interpreted as a combination of medial and lateral compression of the nerve root. No isolated abnormality of CMCT to the AH muscle and/or to the TA muscle (implying medial compression of the root) appeared. The results of the current study did not confirm those of Bischoff et al., which appeared to demonstrate that there are no major differences between MEPs and EMG in terms of their sensitivity in detecting nerve root compression [18]. In the current study, the sensitivity of EMG exceeded that of MEPs. The different results of our study and that of Bischoff et al. can be elucidated by the different inclusion criteria. Bischoff investigated patients with clinically symptomatic radiculopathy with frequent occurrence of muscle weakness and the correlation between muscle weakness

Figure 1
Diagnostic contribution of electrophysiological tests in patients with LSS

EMG/NCS  81.4
EMG/NCS+SEP  86.3
EMG/NCS+SEP+MEP  87.3

Figure 1
Diagnostic contribution of electrophysiological tests in patients with LSS
and pathological MEP latency was demonstrated (that’s why the sensitivity of MEPs was high). On the contrary, in the study of Bischoff only the presence of spontaneous EMG activity in muscles was regarded as a pathological finding but in our study the change of parameters of MUAPs was also regarded as a pathological finding (that’s why the sensitivity of needle EMG was high in our study).

Abnormal SEPs were found in 60 patients with LSS (58.8%) in our study (implying abnormality of SEPs in at least one of three nerves evaluated). In the literature, the positive SEP figures range from 20% to 84% in patients with radiculopathy [27, 28]. The results are substantially influenced by the type of stimulation and definitions of abnormal values. The literature indicates that SEPs make a major contribution in patients with LSS in comparison with the contribution made by SEPs in isolated radiculopathy, possibly because LSS is associated with multiple radiculopathy and a concomitant higher probability of abnormal SEPs [29, 30]. The results in the current study are similar to those of Leinonen, where altered tibial SEPs were observed in 16 of 26 patients with LSS evaluated (in our study, abnormal tibial SEPs were found in 47.1% of the patients) [21].

Of 19 patients with normal EMG, abnormal MEPs appeared in one, abnormal SEPs in 4 patients, and abnormalities of both SEPs and MEPs appeared in one patient. When abnormalities of any evoked potentials (MEPs, SEPs) were considered, the number of patients with normal electrophysiological findings was reduced from 18.6% to 12.7%. We may conclude that a diagnostic contribution of evoked potentials was documented in LSS patients with normal needle EMG and conduction studies of the lower extremities.

CONCLUSIONS

Nerve conduction studies and needle EMG are the most useful electrophysiological examinations for the evaluation of suspected radiculopathies in patients with LSS. The involvement of L5 and S1 roots is the most common. The diagnostic contribution of evoked potentials (SEPs, MEPs) has limited value in patients with LSS.

REFERENCES