Choosing the Surgical Approach in Cases of Spondylogenic Cervical Myelopathy

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ABSTRACT

The purpose of this study was to evaluate the EMG response in spondylotic cervical myelopathy. The authors proved the dependence of the M-response (the transcranial magnetic stimulation protocol) on compression of the anterior spinal artery. Posterior spinal artery compression caused changing of SSEP registrations.

Based on this correlation, the authors performed anterior decompression with fusion and instrumentation or posterior surgery (laminoplasty) as the main decompression procedure. The average recovery rate was 55% (according to the JOA score) with this protocol. Various EMG methods can therefore be used for screening patients with bilateral spondylotic cervical myelopathy compression.

KEY WORDS: Cervical fusion, Cervical myelopathy, Cervical spine, Degenerative disc disease, Electromyography, Laminoplasty

Each fundamental field of human pathology has unique unmanageable problems. This problem is treatment of compressive cervical myelopathy for spine neurosurgery. Compression length (in case of degenerative cervical stenosis) and clinical features of compression (i.e. a decrease in the axial sectional area of the spinal canal) do not correlate with clinical evidence of compressive cervical myelopathy or with the results of surgical treatment (1). No unified methodology of neural compression evaluation therefore exists. The same is valid for decompressive surgery effectiveness.

The clinical history of compressive cervical myelopathy also presents no specific symptom complex. Emery S. (2) states that manifestation of myelopathy is usually associated with static disorders and urination disturbances. It is known that most patients in the first stage of the disease suffer from neck and arm pains not associated with movement; nevertheless, about 20% have no pain symptoms. An expanded clinical picture of myelopathy leads to severe efferent disorders in different muscle groups of the upper extremities with specific pathological reflexes (perversed carporadial reflex, Hoffmann reflex). However, the neurological symptoms of cervical myelopathy are limited to spastic lower paraparesis and pyramidal syndrome without any disorders in the arms in 15% of cases in our experience.

Tsuyama (3) published in 1984 the results of the Japanese Ministry of Health study. The clinical status of 2125 patients with ossification of the posterior longitudinal ligament (OPLL) associated with cervical myelopathy was studied. The prevalence of clinical signs as described in that study is presented in Table 1.

As we see, only 20% of the patients had weakness in the arms as the main feature of disease while urination disturbances in just 1% of the patients. Length and spread is absolutely specific for OPLL, though the ischemic process in the spinal cord has its usual nature. It is supposed that the variation of clinical features in cervical myelopathy is associated with different locations of the
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Table 1: The prevalence of OPLL clinical signs

<table>
<thead>
<tr>
<th>Clinical signs</th>
<th>Prevalence, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck pain</td>
<td>42</td>
</tr>
<tr>
<td>Sensory disturbance in arms</td>
<td>48</td>
</tr>
<tr>
<td>Weakness in arms</td>
<td>19</td>
</tr>
<tr>
<td>Weakness in legs</td>
<td>15</td>
</tr>
<tr>
<td>Urination disturbances</td>
<td>1</td>
</tr>
</tbody>
</table>

ischemic focus in the spinal cord, which corresponds to the perfusion zone of the compressed spinal or segmental artery. Spondylogenic cervical compressive myelopathy is therefore a typical pathological process of ischemia, and the target of the compressive factor is the spinal arteries (anterior and posterior) as well as their branches.

Delamarter R.B. (4) believes that the critical ratio when the decrease in the cervical spinal canal cross-section becomes symptomatic is 40% (or 30 mm²). The original system for types of spinal stenosis with an unfavourable prognosis still exist (Turel) (5) (Figure 1). The “banana” type of spinal canal is the most favourable for post-op recovery. This “fruit” metaphor of stenosis looks banal, but has an explanation: the maximal compression of the anterior spinal artery and ischemia in the most functionally important zone of efferent pathways (Figure 2).

Together with the geometrical characters of spinal canal cross-section, there is another method that reveals the main direction of spinal cord compression and enables determining surgical tactics for decompression based on lateral spondylogram. This method was described by Dickman C.A. & Marciano F.E. (6) in 1996. It requires the application of a “grey zone” to the lateral spondylogram on cervical level at the usual head position (Figure 3). Two points are then drawn on opposite sides over a distance 4 mm from the middle of the line that joins the posterior caudal lines of C2 and C7 and these points are connected with the end of the C2-C7 lines. This symmetric rhombus is the “gray” zone. The location of the altered vertebral segment (herniation, posterior osteophyte) in front of the “gray” zone is a sign of lordosis effectiveness; kyphosis effectiveness if it is dorsal to the “gray” zone

Figure 1: Significant prognostic variants of spinal canal form in case of cervical myelopathy and post-operative recovery (from Turel R., 2005).

<table>
<thead>
<tr>
<th>Total number of patients</th>
<th>32</th>
<th>“Oval”</th>
<th>“Heart”</th>
<th>“Banana”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full recovery</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Satisfactory recovery</td>
<td>20</td>
<td>16</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>No changes</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 2: Perfusion of the corticospinal tract by the anterior (A) and posterior (B) spinal arteries.
and straightening of cervical spine if it is in the area of the “gray” zone. The combination of cervical myelopathy clinical features and x-ray signs of kyphosis is an indication for anterior decompression; the combination of myelopathy and effective lordosis should be treated with posterior decompression.

Various indications for a surgical approach in cervical myelopathy have been stated based on the above-mentioned x-ray criteria (Benzel E., 1993; Tomazzi A., 2005). The anterior cervical approach with discectomy/corporectomy, fusion and, if necessary, spine fixation, is indicated in cases of kyphosis, verified anterior compression (MRI data) the length of 2 vertebrae (or more), and severe instability. The posterior median approach (with laminectomy and laminoplasty with/without fusion and fixation) is indicated in cases of elongated (mostly posterior) compression in combination with effective lordosis, ossification of posterior longitudinal ligament and congenital stenosis. Age and co-morbidity of the patient are other factors that influence the decision. Patients older than 65 years (about 30% of our patients with cervical myelopathy) might have other important factors such as osteoporosis, insufficiency of ligamentous apparatus (functional kyphosis) and a high risk of pseudoarthrosis after fusion. The posterior approach as less invasive and is preferable for this group of patients.

However, this decision procedure often does not let us define the direction of decompression unambiguously in patients with myelopathy (especially in cases of spine straightening and bilateral compression). According to our data, about 12% of patients need additional methods of examination to create optimal surgical tactics. The following case illustrates this statement.

Case

Female, 47 years, teacher. Lives in Moscow. Complains of weakness in hands, and numbness in legs from the middle of femur. Disease started spontaneously about 7 years ago with numbness in hands and slowly progressed.

On admission: tetraparesis, mostly seen in hands (4 of 5), mostly distal, pathologic Hoffmann reflexes and carporadial reflexes on both sides, lowering of temperature and pain sensitivity in hands, mostly on the dorsal surface. Lowering of sensitivity in the legs below knees, mostly on the left. No pathological reflexes present in the legs.

Cervical spine MRI (Figure 4-1) revealed aligned cervical lordosis. Osteophytes and fragments of ossification of posterior longitudinal ligament (OPLL) were seen ventrally on C4-C6, and maximally on C5 and C6. A rounded hyperdense shadow (area of myelomalacia) is seen in the spinal cord at the level of C5.

Surgery

Taking into account the ventral compression with osteophytes, the surgical decision was to use the anterior cervical approach with corporectomy of C5 and C6. Elongated continuous ossification of PLL from C4 to C7 was observed during the corporectomy. The osteophytes deeply indented the dural sac and merged with dura mater at this level. Removal of the ossification led to extended damage of the dura mater and increased spinal cord swelling with bulging to defect of dura (Figure 4-2 presents the intra-operative photograph).

The operation was finished with glue plastics of dura mater using synthetic graft and fibrin glue, fusion with allograft and anterior fixation with plate of C4-T1 (Figure 4-3).

Deterioration of the neurological deficiency was seen in the post-operative period with deepening of the lower paraparesis to 2 of 5 and the paresis in left arm to 2 of 5 with following partial resolution.

This case demonstrates an inadequate choice of surgical approach because of incomplete diagnostics (incorrect interpretation of data). Elongated ossification of PLL
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needs a posterior approach in all cases (Hirabayashi K.). This pathology is rare in the European population; it led to an incorrect decision in this case. The isolated anterior approach can be used in case of spine kyphotic deformation and alteration on 1 or 2 levels. In case of combination of kyphotic deformation and osteophyte penetration to the dural sac of more than 5 mm, the combined approach – firstly, posterior, then anterior – is recommended (Delamarter R. & Smith J., 2003). The patient in this case was operated with posterior approach (laminoplasty) later; after operation decreasing of neurological deficiency was seen on the back of active rehabilitation.

Electrophysiological methods

Surgical treatment of spondylogenic cervical myelopathy has been used for more than 15 years in the spine clinic of Burdenko Neurosurgery Institute. A total of 430 patients with different cervical compressive syndromes were operated on during this period. The

Figure 4-1: Cervical spine MRI: sagittal (left) and axial (right) projections (see description in text).

Figure 4-2: Intra-operative photographs. The swollen spinal cord bulges through the damaged dural sac (left). Repair of dura mater glue plastics with synthetic graft (right).

Figure 4-3: Contrast angiography 12 days after the operation. Radicular arteries fill without filling of the anterior spinal artery. Location of allograft and cervical plate is correct.
aim of our study was to state the direction of surgical decompression in cases of degenerative stenosis based on the electrophysiological assessment of sensory and motor conductivity as well as segmental innervation of the cervical spine, with electrophysiological estimation of surgery effectiveness.

A total of 48 patients examined at the Burdenko Neurosurgery Institute since May 2007 for degenerative cervical stenosis by spondilography, MRI, CT Scan, as well as by electrophysiological methods (SSEP, electroneurography, transcranial magnetic stimulation) were included to the study. All patients were operated with decompressive surgery. The results were evaluated depending on the main clinical syndrome according to the international representative scales (the JOA scale was used in case of cervical myelopathy as the leading syndrome).

**Description of method**

Electrophysiological studies can help to answer the following questions:

1. Which pathways are altered?
2. Which spinal segments are responsible for pain and/or hyperpathic irritation?
3. Does this alteration have a chronic, acute or progressing character?
4. Is the functional disorder treatable?

Used methods and their differentiated usage are mentioned in Table 2.

**SOMATOSENSORY EVOKED POTENTIALS (SSEP)**

Registration of SSEP at the cervical level (cervical intumescence) was realized using stimulation of median, ulnar and radial nerves at the wrist. Only short-latent SSEP were used in our study. Somatic afferentation through the median nerves from both sides (interval N13-N19) was estimated according to the indexes of latency and response amplitude at take-over point.

**TRANSCRANIAL MAGNETIC STIMULATION (TMC) (Barker et al 1985):**

TMS is the most objective method of study of efferent impulses conduction. Magnetic stimulation was realized by coil, generating impulses of magnetic field with strain 4.2 Tl. Points of stimulation were the motor cortex and cervical roots. Points of registration were the field of biceps; m. abducens hallucis and pollicis and the anterior tibial muscle.

The main indexes of evoked motor response (EMR) were latency, amplitude, length, limit and shape. The most important index was the **time of central motor conduction** (TCMC), i.e. the time of the impulse running through efferent neurons from the cortex to the cervical roots. It is determined by the difference of EMR (time in sec) during stimulation of motor cortex and cervical roots. According to Dvorak (2002), an increase in TMC means compression of the spinal motor neuron, i.e. anterior spinal compression as result of ischemic process in perfusion zone of anterior spinal artery in more than 80% of cases.

**NEUROGRAPHY AND EMG**

This study gives information about the condition of root apparatus and peripheral nerves and also characterizes neuromuscular transmission. The most important characteristics are called F-waves (Magladery & McDougal, 1950). They are the “late” muscular component, which is
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Points of stimulation and registration during this study varied and the main characteristics were indexes of latency, time of conduction and amplitude.

We found following the complex estimation of all the methods mentioned above that the reliability of electrophysiological methods in case of single use is 30%-60% (Vohanka & Dvorak, 1993). The reliability increases to 80% and more if these tests (SSEP, TMS, EMG) are used together.

**RESULTS**

We examined 48 patients with spondylogenic cervical myelopathy. Electrophysiological examination was used additionally if no clear direction of compression was seen and we could not use above-mentioned algorithm. Ischemic changes in the perfusion area of the anterior spinal artery – in the zone of the corticospinal tract (Figure 2) – determined lowering of the M-response at TMS (Figure 5).

If the time of central motor conduction (TCMC) and/ or latency are increased more than 30% from normal (using the data of transcranial magnetic stimulation), and elongated (more than 2 segments) compression is absent in combination with the presence of effective lordosis, ossification of the posterior longitudinal ligament and congenital stenosis, ischemic alteration is localized in the zone of efferent pathways and associated with compression of the anterior spinal artery. In such cases, we used anterior decompression (discectomy or corporectomy) with fixation or disc prosthesis (Figure 6).

If the latency and time of central sensor conduction (points N13-N19 – posterior columns of the cervical spine on C2-C7) are increased (according to SSEP data), but the results of the TMS are normal, ischemic compressive alteration is associated with mostly dorsal compression (Figure 7). Such patients were operated by laminoplasty if signs of level instability were absent (Figure 8).

Asymmetry of conduction parameters was seen in some cases and confirmed with electroneuromyographic study of the involved roots (Figure 9). Monolateral alteration means lateralization of the compression factor. It can be confirmed with x-ray data and should be treated with lateral widening of the standard anterior approach (Figure 10).

The treatment results were evaluated using representative scales used for such studies in world practice. The basis for the degree of neurological recovery was the JOA (Japanese Orthopaedic Association) scale. This scale is convenient because we can calculate the Recovery Rate using the following formula:

![Figure 5: Electrophysiological data 1.](image)
Figure 6: 1. Patient R.; clinical features of spondyloegenous cervical myelopathy. Results of electrophysiological studies are described on Figure 5. a) – pre-op CT Scan (axial slice on C5 level) b) – pre-op MRI (sagittal projection) According to pre-op studies, bilateral compression by osteophytes without spine kyphosing is seen. 2. Intra-op photo. Implant is positioned into the cavity of removed disc. 3. Control CT Scan (left) and spondylography (right).

Figure 7: Electrophysiological data 2. a) SSSP during stimulation of median nerve. Point of stimulation - carpus. Point of registration – level of C5-C6 spinous processes and sensor cortical projection. Bilateral increase of the latent period N13 is seen: 15.2; 15.9 (normal range: 13.4±0.3). Disturbance of somatosensory afferentation on the level of cervical intumescence is seen as well. Time of central sensory conduction is 7.5 msec (normal ranges: 5.6 ±0.5). b) Results of TMS. Indexes of IMR are not altered.
Comparing groups of patients with different morphological reasons for cervical myelopathy (disc herniation, spine stenosis) with groups of patients where the surgical approach was based on clinical, x-ray and electrophysiological criteria revealed a significantly increased recovery rate (Rr) in the second group (Figure 11). Schimandle J. supposes that reaching a 50% recovery rate means a significant improvement of life quality for patients with spondylogenic cervical myelopathy. Most scientists believe that this limit is 42-48%.

Figure 8-1: Patient V; clinical features of spondylogenous cervical myelopathy. Results of electrophysiological studies are described on Figure 7. a)–pre-op MRI (sagittal projection). Diagnosis: Spine stenosis on C3-C5 level. b)–pre-op MRI (axial projection). According to pre-op studies, bilateral compression by osteophytes without spine kyphosing is seen.

Figure 8-2: Intra-op photo and chart of Hirabayashi laminoplasty.

Figure 8-3: Laminoplasty: pre-op CT (left) and post-op CT (right). Significant enlargement of spinal canal sagittal size.
Figure 9: Electrophysiological data 3. 
a) SSSP during stimulation of median nerve. Point of stimulation - carpus. Point of registration - level of C5-C6 spinous processes and sensor cortical projection. Increasing of latent period N13 from the right is seen – D (increasing of conduction time on pathway “right median nerve – upper cervical level C5-C6”). 
b) Results of electroneuromyography. Indexes of distal latency and conduction time for motor fibers of right and left median nerves. Signs of C5-C6 right motor roots dysfunction are seen.

Figure 10-1: Patient L.; clinical features of spondylogenous cervical myelopathy. Results of electrophysiological studies are described on Figure 9. 
a)– pre-op MRI (sagittal projection). 
b)– pre-op MRI (axial projection). Diagnosis: Disc herniation and lateral osteophytes on C5-C6 from the right.

Figure 10-2: Chart and intra-op photo of anterior discectomy and laminoforaminotomy with root decompression.
CONCLUSIONS

- compressive disturbances in case of cervical spinal canal stenosis have a localized ischemic nature and correspond to the perfusion zone of the compressed spinal or segmental artery,
- there is correlation between localization of ischemic compressive focus and the character of electrophysiological conductivity and responses,
- differentiated character of surgical decompression operations provides better results for neurological recovery and enables following the principles of less invasive surgery.

REFERENCES