Neuropsychological Improvement in Patients With Cervical Spondylotic Myelopathy After Posterior Decompression Surgery

Minoru HOSHIMARU

Department of Neurosurgery, Ohtsu Municipal Hospital, Ohtsu, Shiga

Abstract

Patients with cervical spondylotic myelopathy sometimes complain of cognitive dysfunction, which may be coincidence. However, cognitive dysfunction may be related to disorders of the cervical spine and/or spinal cord. This study investigated cognitive dysfunction in patients with cervical spinal disorders. A total of 79 patients with cervical spondylotic myelopathy (40 women and 39 men, mean age 61.2 years) underwent cervical laminoplasty between January 2006 and July 2007. Ten of these 79 patients (7 women and 3 men, mean age 65.2 years) complained of moderate to severe memory disturbances. These 10 patients underwent neuroimaging studies and a battery of neuropsychological tests consisting of the mini-mental state examination, Kohs Block Design Test, Miyake Memory Test, Benton Visual Retention Test (BVRT), and “kana-hiroi” test before and 3 months after surgery. Brain magnetic resonance imaging showed no organic brain lesions in the 10 patients, but single photon emission computed tomography demonstrated reduced regional cerebral blood flow in the posterior cortical areas in eight patients before surgery. Neuropsychological test scores showed statistically significant improvement after surgery in the Kohs Block Design Test and the BVRT, which measure visuospatial perception and reflect the function of the parietal and/or occipital lobes (p < 0.05). The practice effect may have contributed to the neuropsychological improvements, but this study suggests that cervical spinal disorders may affect cognitive functions and that surgical treatment can ameliorate such effects.

Key words: cognitive dysfunction, cerebrospinal fluid, neuropsychological test, single photon emission computed tomography, cervical laminoplasty

Introduction

Patients with cervical spondylotic myelopathy sometimes complain of memory disturbance, which is normally considered to be coincidence. However, disorders of the cervical spine and/or spinal cord are known to affect cognitive functions. Various studies have reported impairment in cognitive performance in patients with whiplash injury, and high frequency of cognitive impairment occurs after spinal cord injury. As many as 40% to 60% of patients with acute spinal cord injury demonstrate various types of cognitive deficits, including poor attention and concentration, disturbed memory and learning, impaired visuospatial perception, and decreased problem-solving ability. In addition, significant decrease of regional cerebral blood flow (rCBF) has been demonstrated in some brain regions in paraplegic and tetraplegic patients in contrast to increased cerebral perfusion in patients and experimental animals undergoing spinal cord stimulation through a cervical lead.

Neuropsychological studies were conducted in patients with cervical spondylotic myelopathy who complained of memory disturbance before and after posterior decompression surgery of the cervical spine.

Materials and Methods

A total of 79 patients with cervical myelopathy, 40 women and 39 men aged from 31 to 82 years (mean 61.2 years), who underwent cervical laminoplasty for decompression of the cervical cord and/or cervical nerves between January 2006 and July 2007. Ten of these 79 patients, 7 women and 3 men aged from 39 to 79 years (mean 65.2 years), complained of moderate to severe memory disturbances that disturbed activities of daily living. These 10 patients
underwent neuropsychological and neuroimaging evaluations including single photon emission computed tomography (SPECT) imaging and brain magnetic resonance (MR) imaging after informed consents were obtained. The study was approved by the institutional review board and the investigators fully respected and followed the current version of the declaration of Helsinki (Tokyo, 2004). Brain MR imaging demonstrated no organic brain lesions except mild brain atrophy in these patients. The clinical characteristics and data of these patients are summarized in Table 1.

Neuropsychological evaluations used a battery of neuropsychological tests consisting of the mini-mental state examination (MMSE), Kohs Block Design Test, Miyake Memory Test, Benton Visual Retention Test (BVRT), and “kana-hiroi” test. These tests were carried out individually by the same assessor before and 3 months after surgery. The MMSE is a simplified, scored form of the cognitive mental status examination which can be used for the serial testing of the cognitive mental state. The mean scores in the sixth decade, seventh decade, and eighth decade are 28, 28, and 27 out of 30, respectively. The Kohs Block Design Test is recognized as a standard clinical tool for detection of visuospatial disorganization, which indicates malfunction of the parietal lobe. We used this test in its complete form with 17 designs and calculated the intelligence quotient (IQ) according to the Manual for Kohs Block Design Test (catalogue No. 37000; Stoelting, Chicago, Ill., U.S.A.). The mean IQ in normal elderly subjects is reported to be 77.9. The Miyake Memory Test tests the recent memory of verbal materials in Japanese. The mean score in the seventh decade is 9.9 out of 10 in the related word test and 5.4 out of 10 in the unrelated word test. The BVRT is a test of memory for designs and visuo-constructional skills. A greater number of errors on the BVRT is associated with an increased risk of Alzheimer disease in normal elderly subjects. The “kana-hiroi” test is useful for the detection of frontal lobe cognitive functions. In this test, the following five kana letters “A, I, U, E, and O” (Japanese vowels) are identified while reading the story written in kana. The number of recognized letters is known to decrease with age, and the mean number in the sixth decade is 25 out of 61.

Brain SPECT imaging were obtained after intravenous injection of N-isopropyl-p-[123I]iodoamphetamine and analyzed using an easy Z-score imaging system as described elsewhere. A positive Z-score indicates lower rCBF in a patient compared to the normal control database. Z-score maps were dis-

Table 1 Clinical summary of 10 patients with cervical spondylotic myelopathy and cognitive dysfunction

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Chief complaints</th>
<th>JOA score Pre</th>
<th>JOA score Post</th>
<th>MMSE Pre</th>
<th>MMSE Post</th>
<th>KBDT (IQ) Pre</th>
<th>KBDT (IQ) Post</th>
<th>MMT Pre</th>
<th>MMT Post</th>
<th>BVRT Pre</th>
<th>BVRT Post</th>
<th>KHT Pre</th>
<th>KHT Post</th>
<th>Areas showing reduced rCBF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>64</td>
<td>M</td>
<td>paresthesia and motor weakness (UE)</td>
<td>12.5</td>
<td>15.5</td>
<td>25</td>
<td>27</td>
<td>79</td>
<td>79</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>31</td>
<td>29</td>
<td>bil P and O, bil P and O</td>
</tr>
<tr>
<td>2</td>
<td>79</td>
<td>F</td>
<td>paresthesia (UE)</td>
<td>12</td>
<td>15</td>
<td>26</td>
<td>30</td>
<td>79</td>
<td>79</td>
<td>106</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>7</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>62</td>
<td>F</td>
<td>shoulder pain, motor weakness</td>
<td>15</td>
<td>17</td>
<td>28</td>
<td>30</td>
<td>74</td>
<td>89</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>27</td>
<td>36</td>
<td>bil F and P, bil PCG, bil PCG</td>
</tr>
<tr>
<td>4</td>
<td>74</td>
<td>F</td>
<td>spastic gait</td>
<td>14</td>
<td>16</td>
<td>29</td>
<td>29</td>
<td>73</td>
<td>79</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>25</td>
<td>reduction (-) ND</td>
</tr>
<tr>
<td>5</td>
<td>66</td>
<td>F</td>
<td>paresthesia (UE)</td>
<td>16</td>
<td>17</td>
<td>29</td>
<td>28</td>
<td>82</td>
<td>93</td>
<td>6</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>21</td>
<td>33</td>
<td>reduction (-) Nd</td>
</tr>
<tr>
<td>6</td>
<td>53</td>
<td>M</td>
<td>paresthesia (UE + LE)</td>
<td>13</td>
<td>16.5</td>
<td>30</td>
<td>29</td>
<td>99</td>
<td>102</td>
<td>6</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>29</td>
<td>27</td>
<td>bil O, bil PCG, bil PCG, bil PCG</td>
</tr>
<tr>
<td>7</td>
<td>67</td>
<td>F</td>
<td>paresthesia (UE + LE)</td>
<td>13</td>
<td>15</td>
<td>28</td>
<td>28</td>
<td>50</td>
<td>54</td>
<td>3</td>
<td>1</td>
<td>13</td>
<td>11</td>
<td>5</td>
<td>10</td>
<td>bil P and O, bil PCG, bil PCG</td>
</tr>
<tr>
<td>8</td>
<td>73</td>
<td>F</td>
<td>shoulder pain, motor weakness</td>
<td>14</td>
<td>16.5</td>
<td>28</td>
<td>29</td>
<td>72</td>
<td>79</td>
<td>8</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>13</td>
<td>15</td>
<td>ND</td>
</tr>
<tr>
<td>9</td>
<td>75</td>
<td>M</td>
<td>motor weakness (UE)</td>
<td>14.5</td>
<td>16.5</td>
<td>26</td>
<td>30</td>
<td>70</td>
<td>85</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>6</td>
<td>13</td>
<td>25</td>
<td>bil O, it PCG, BG, it F, cerebellum, bil O, cerebellum, bil PCG</td>
</tr>
<tr>
<td>10</td>
<td>39</td>
<td>F</td>
<td>paresthesia and motor weakness (UE)</td>
<td>12</td>
<td>15.5</td>
<td>29</td>
<td>30</td>
<td>98</td>
<td>109</td>
<td>10</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>31</td>
<td>34</td>
<td>reduction (-)</td>
</tr>
</tbody>
</table>

Mean 65 13.6 16.1 27.8 29 77.6 89 4.3 4.8 6.1 5 20.1 25

played by overlay on tomographic sections or by projection with averaged Z-score of 14 mm thickness onto surface rendering of the anatomically standardized MR imaging template.

Cervical laminoplasty was conducted according to the procedure described before. Briefly, expansive open-door cervical laminoplasty using hydroxyapatite implants was performed through a short skin incision, which enabled reconstruction of a rigid enlarged spinal canal from C2 to C7 with minimal disruption of the posterior supporting element of the cervical spine. Surgical results were evaluated according to the Japanese Orthopedic Association (JOA) score for cervical myelopathy. No treatments intended to improve cognitive functions such as cholinesterase inhibitors and speech therapy were administered after surgery.

The paired Student’s t test and the Wilcoxon signed-rank test were used to assess the differences between preoperative and postoperative neuropsychological test scores. The difference was judged to be statistically significant if both tests indicated \( p < 0.05 \).

Results

All 10 patients who complained of moderate to severe memory disturbances were aware of dullness of thinking and characteristically displayed general slowness of mental activity during daily conversations. However, no drastic deviations in neuropsychological test scores from the normal data were observed. The patients underwent cervical laminoplasty to alleviate symptoms of cervical myelopathy, such as sensory and/or motor disturbance of the extremities, and the symptoms of cervical myelopathy improved after surgery. The mean JOA scores was 13.6 before and 16.1 after surgery. Interestingly, all 10 patients expressed clearness of thinking after surgery.

Both the Kohs Block Design Test and the BVRT scores demonstrated statistically significant improvement after surgery \( (p < 0.05, \text{Fig. 1}) \). The other neuropsychological tests observed slight and statistically insignificant increases in scores after surgery (Table 1).

All 10 patients underwent CBF study using SPECT before surgery. rCBF was decreased in the parietal and/or occipital lobes in eight patients (Table 1). CBF study was performed after surgery in 6 patients. Areas of decreased rCBF were diminished in 3 patients (Cases 5, 9, and 10).

Illustrative case: A 75-year-old man (Case 9) suffered motor weakness of the bilateral fingers and mild clumsiness of gait. He also complained of memory disturbance and dullness of thinking. His conversation was slow and roundabout. Cervical MR imaging revealed cervical spondylosis obstructing the subarachnoid space. Brain MR imaging demonstrated no organic lesions except mild brain atrophy. Cervical laminoplasty from C2 to C7 was performed, which resulted in good expansion of the subarachnoid space sur-
rounding the spinal cord (Fig. 2D). Preoperative neuropsychological tests revealed mild impairment of verbal and visual memory, although language function was well preserved. Preoperative SPECT showed reduced rCBF in the bilateral occipital lobes, left posterior cingulate gyrus, bilateral basal ganglia, left frontal base, and the left cerebellum (Fig. 3 left column). His symptoms of the limbs disappeared after surgery. In addition, his mental activities including visual memory and calculation improved after surgery, although verbal memory was similar. Areas of reduced rCBF including the posterior cingulate gyrus were diminished after surgery (Fig. 3 right column).

**Discussion**

This study suggests that disorders of the cervical spine affect cognitive functions and that surgical treatment for the spinal disorders can ameliorate the associated cognitive malfunctions, but there are limitations to the protocol. Firstly, the neuropsychological test scores may have improved due to the practice effect, as the patients may have become accustomed to the neuropsychological test at the first examination and thus achieved better scores at the second examination. However, this practice effect is unlikely because the postoperative tests were performed 3 months after the preoperative tests. Such a test-retest interval of 3 months is long enough to abolish the practice effect in such complicated neuropsychological tests as the Benton Visual Form Discrimination Test.\(^7,11\) Secondly, the SPECT imaging was a qualitative study and did not obtain absolute values of rCBF.

Despite these limitations, some aspects of this study merit special attention. The neuropsychological data suggest that visual cognitive functions may be affected by cervical myelopathy and improved by cervical laminoplasty, corresponding to the improvement of the reduced rCBF in the parietal and/or occipital lobes shown by SPECT imaging. This association between neuropsychological data and SPECT findings is also observed in patients with Alzheimer disease. Poor performance in the BVRT may represent early expression of Alzheimer disease,\(^17\) which begins with reduction of rCBF in the posterior cortical areas including the posterior cingulate gyri and precunei.\(^22\) Cognitive malfunction and reduction of rCBF in the posterior cortical
areas are also observed in various pathological states outside the skull including chronic heart failure and whiplash injury. Reduction of rCBF in patients with chronic heart failure is considered to be due to low cardiac output and is directly correlated with the degrees of cognitive impairment. Patients with whiplash injury show considerable impairment in tasks requiring working memory, and SPECT or positron emission tomography have demonstrated parieto-occipital hypoperfusion, although computed tomography and MR imaging failed to delineate traumatic brain lesions. Such parieto-occipital hypoperfusion and hypometabolism observed in patients with whiplash injury may result from activation of nociceptive afferents from the upper cervical spine.

There are several explanations for the neuropsychological improvement after decompression surgery of the cervical spine. First, amelioration of motor and/or sensory disturbances may have contributed to the improvement of the neuropsychological test scores, because motor disturbances of the upper limbs may worsen the scores in the Kohs Block Design Test and BVRT by inhibiting hand operations, and pain and/or dysesthesia may cause anxiety or depression, which may affect the mental status and consequent cognitive functions. Second, substantial evidence supports neural control of the CBF through the sympathetic nerves from the superior cervical ganglion, through the trigeminal nerves, and through the somatosensory input. All of these nerves can be affected by cervical cord lesions. Third, blockade of cerebrospinal fluid (CSF) flow within the spinal canal may interfere with brain functions. According to the Monro-Kellie hypothesis, the sum of the volume of the brain plus the CSF volume plus the intracranial blood volume is constant within the closed sphere of the skull. Therefore, an increase in one factor should cause reduction in one or both of the other two. Changes in the intracranial blood volume caused by arterial pulsation are considered to be compensated by the bi-directional CSF flow through the foramen magnum, outflow toward the spinal canal in systole and reverse flow during the diastole, as demonstrated by phase-contrast MR imaging. The subsequent change in the CSF volume within the spinal canal is considered to be damped by distension of the dural sac and volume reduction of abundant compressible epidural tissues such as adipose tissue and venous plexus. Myelography has revealed volume change of the thoracolumbar dural sac subsequently to inhalation of 10% CO2 in oxygen or hyperventilation. Therefore, the function of the spinal dural sac and the epidural tissues as a damper may permit the vascu-

References

9) Crum RM, Anthony JC, Bassett SS, Folstein MF: Population-based norms for the mini-mental state ex-
Neuropsychological Improvement After Cervical Laminoplasty

559

amination by age and educational level. JAMA 269: 2386–2391, 1993


Address reprint requests to: Minoru Hoshimaru, M.D., Department of Neurosurgery, Ohtsu Municipal Hospital, 2–9–9 Motomiya, Ohtsu, Shiga 520–0804, Japan.
e-mail: hoshimar-kyt@umin.net

Neurol Med Chir (Tokyo) 50, July, 2010