Cervical compressive myelopathy is one of the most common neurologic disorders increasing in the geriatric population. It is caused by cervical spondylosis, disc herniation, and ossification of the longitudinal ligament. Symptoms include sensory disturbances of the extremities, clumsiness of hands, gait disturbance, and urinary dysfunction. Decompressive surgery is the accepted treatment of this disorder. However, in determining the severity of any disease process, the effects of surgical intervention, or the factors that influence prognosis and survival, it is essential to have an objective and reproducible means of measuring the patient’s disability before and after treatment.

Various clinical grading systems have been used to assess the severity of cervical compressive myelopathy. Most of them include subjective grading assessment of the patient’s symptoms, such as clumsiness of hands, gait disturbance, and urinary dysfunction. However, these measures are poorly quantitative with very few and large arbitrary categories. The sensitivity to change is likely to be poor because 1 category of dysfunction covers a huge range of actual functional severity. Moreover, they lack the objectivity of a clinical neurologic examination. For example, a scale based on patients’ symptoms might be colored by their psychological state and by expecting degree of treatment. Experimentally clinicians are aware that patients with myelopathy experience difficulty in taking a step while walking, due to disorders of position sense and locomotor disability in the lower extremities, which reflect long tract pathology. Hence, it was assumed that the step test could be used as a scale to quantify the severity of cervical compressive myelopathy.

Thus, we developed a 10 second step test (step test) as a quantifiable measure of severity in cervical compressive myelopathy. The purpose of this study is to establish the standard value of a 10 second step test in healthy volunteers and to verify its clinical effectiveness in patients’ with cervical compressive myelopathy.

### Methods

#### Patients

One hundred sixty-three patients with cervical compressive myelopathy who would undergo decompressive surgery in our hospital were studied. The patients included 99 men and 64 women with a mean age of 63.3 ± 12.3 years. The diagnosis was confirmed by both physical neurologic tests performed by certified spine surgeons and imaging tests with magnetic resonance imaging and computed tomography myelogram. The patients who were concurrently suffering from other locomotor disorders, such as cerebral palsy (CP), rheumatoid arthritis...
IV. Bladder function

III. Sensory function

Table 2. JOA Score

<table>
<thead>
<tr>
<th>Generation</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>20–29</td>
<td>99</td>
<td>98</td>
<td>197</td>
</tr>
<tr>
<td>30–39</td>
<td>103</td>
<td>99</td>
<td>202</td>
</tr>
<tr>
<td>40–49</td>
<td>100</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>50–59</td>
<td>97</td>
<td>103</td>
<td>200</td>
</tr>
<tr>
<td>60–69</td>
<td>101</td>
<td>103</td>
<td>204</td>
</tr>
<tr>
<td>70–79</td>
<td>100</td>
<td>101</td>
<td>201</td>
</tr>
<tr>
<td>Total</td>
<td>600</td>
<td>604</td>
<td>1204</td>
</tr>
</tbody>
</table>

The patients were also examined for the number of finger grip and release (G and R) in 10 seconds (G and R test)\(^1\) and the Japanese Orthopedic Association score for cervical compressive myelopathy (JOA score)\(^2\) (Table 2). Improvement in postoperative symptomatology was evaluated using the recovery rate of JOA score \((\text{postoperative JOA score-preoperative JOA score})/(17-\text{preoperative JOA score}) \times 100\%)\), where 100% recovery rate indicated the best postoperative improvement.

Statistical Analysis

A standard StatView (SAS Institute, Cary, NC) software package was used for statistical analysis. Nonparametric analysis with the Mann-Whitney \(U\) test was used for analyzing differences between the 2 groups and the Kruskal-Wallis test followed by the Mann-Whitney \(U\) test for analyzing differences among the 3 groups. Repeated measures analyses of variance in the same group were performed using the Wilcoxon test. The reproducibility of test was validated using Spearman rank correlation coefficient. \(P\) value <0.05 was considered statistically significant.

Results

The average number of steps in patients was 10.7 ± 5.5 before surgery. The average number of G and R in patients was 16.4 ± 6.1 in right hand, 16.7 ± 6.2 in left hand, and 15.5 ± 6.2 in worse side. Mean JOA score of patients was 10.3 ± 2.8 before surgery. The 10 second step tests were performed twice in 79 cases the results of which were 11.2 ± 5.1 in first and 11.5 ± 5.5 in second tests. There was a strong correlation between both tests in Spearman rank correlation coefficient \((r = 0.89, P < 0.001)\), indicating that the test was highly reproducible. The number of steps significantly correlated with the number of G and R \((r = 0.532, P < 0.0001)\), the walking grade of JOA scores \((r = 0.841, P < 0.0001)\), and total JOA score \((r = 0.664, P < 0.0001)\) (Figure 1). The data from the step test in each motor function of the lower extremities is shown in Table 3.

The data of healthy volunteers in each gender and each generation is shown in Table 4. The average num-

Table 2. JOA Score

1. Motor Function of the Upper Extremity
   - Impossible to eat with chopsticks or spoon
     - Possible to eat with spoon, but not with chopsticks
     - Possible to eat with chopsticks, but inadequate
     - Possible to eat with chopsticks, but awkward
     - Normal
2. Motor function of the lower extremity
   - Impossible to walk
     - Needs cane or aid on flat ground
     - Needs cane or aid only on stairs
     - Possible to walk without cane or aid but slowly
     - Normal
3. Sensory function
   - Upper extremity
     - Apparent sensory loss
     - Minimal sensory loss
     - Normal
   - Lower extremity (same as A)
   - Trunk (same as A)
4. Bladder function
   - Complete retension
     - Severe disturbance (sense of retension, dribbling, incomplete continence)
     - Mild disturbance (urinary frequency, urinary hesitancy)
     - Normal
bers of steps in volunteers was 19.6 ± 3.5. There was a significant difference in the 10 second step test between men and women (Table 4). The number of steps decreased with age in controls (Figure 2). There was a significant negative correlation between age and the 10 second step test (r = −0.412, P < 0.0001).

The number of steps in 10 seconds was significantly lower in patients than in controls and decreased with the age of both the patients and controls (Figure 3). One hundred twenty-three patients were retested at 12 months after surgery. In these patients the average data of the step test were 10.4 ± 5.9 before surgery and 14.0 ± 5.4 after surgery (Figure 4). The mean data of G and R test (worse side) were 15.2 ± 6.2 before surgery and 18.4 ± 5.0 after surgery. Mean JOA score of patients was 10.3 ± 2.9 before surgery and 13.5 ± 2.6 after surgery. The recovery rate of JOA score was 50.1 ± 30.1%. A step test, G and R test and JOA score showed significant postoperative improvement (P < 0.0001).

## Discussion

A new locomotor scale “10 second step test” was investigated to determine if it could be used as a quantifiable parameter for cervical compressive myelopathy. The present study demonstrates that the step test can reflect and quantify the severity of cervical compressive myelopathy. This test can easily be performed anywhere and at any time without the requirement of a special instrument and repeated if necessary, as it is sensitive to neurologic impairment, particularly locomotor function of the lower extremities. A standard value for the 10 second step test in each generation and each gender were derived from a large number of healthy volunteers. This allowed the estimation of severity in patients with cervical compressive myelopathy. This test also has a possibility to reveal silent patient who do not recognize their own symptoms compared with healthy persons, as an accessible screening test. The average score of the step test in 1204 healthy volunteers was 19.6 ± 3.4. The value 12.8 (average−2SD) in this test can be used as the border between normal and patients with a possibility of cervical compressive myelopathy.

Myelopathy secondary to spondylosis typically has an insidious onset, developing over a prolonged period. The natural history is characterized by long intervals of clinical stability punctuated by short periods of worsening and ultimately intermittent progression. Once myelopathy occurs, total reversal is rare. Rarely do patients regain neurologic normality and spontaneous remission of symptoms is unlikely. A standardized grading system for myelopathy would allow a more complete understanding of the natural history of this disorder and provide valid means of comparing the results of the different treatment methods. Furthermore, the system of neurologic assessment and classification must be sufficiently reliable to allow accurate comparison of serial observations by the same or different observer.

Multiple variables, including biologic and physiologic variables, and physician-derived symptom status, must be considered in the measurement of clinical outcomes. These clinical variables include patient symptoms, physical findings, and laboratory investigations which are prone to reporting biases. A variety of traditional outcome measures have been reported in evaluating the severity of cervical compressive myelopathy. The most commonly used are the Ranawat classification, Nurick classification, and the JOA score. The Ranawat classification scale was originally devised to evaluate the neurologic function of patients undergoing cervical spine arthrodesis for rheumatoid involvement of cervical spine. Nurick proposed a grading scheme to measure the degree of walking difficulty in patients with myelopathy secondary to cervical spondylosis. The JOA score is the most comprehensive of the traditional measures in quantifying the degree of impairment secondary to myelopathy. These classifications are determined by questioning the patients. However, they seem to lack the objectivity of a clinical neurologic examination. For example, a scale based on patients’ symptoms might be colored by their psychological state and by expecting degree for treatment. These measures are also poorly quantitative with very few and largely arbitrary categories. The sensitivity to change is likely to be poor because one category covers a wide range of clinical severity.

Two quantifiable tests for cervical compressive myelopathy were reported: the 10 second G and R test and the 30 m walking test. The G and R test can reflect motor disability of upper extremities quantitatively and distinguish the laterality of symptom. The test is influenced not only by long tract symptom but also segmental symptom. The walking test was reported to be a suitable measure of severity of CSM.

### Table 3. Cases and 10 Sec Step Test of Patients in the Motor Function Grading of Lower Extremities in JOA Score

<table>
<thead>
<tr>
<th>Motor Function of LE</th>
<th>No. of Patients</th>
<th>10 Sec Step Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>6</td>
<td>0 ± 0</td>
</tr>
<tr>
<td>1</td>
<td>29</td>
<td>2.9 ± 3.66</td>
</tr>
<tr>
<td>2</td>
<td>58</td>
<td>10.6 ± 2.67</td>
</tr>
<tr>
<td>3</td>
<td>39</td>
<td>13.9 ± 2.28</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>18.3 ± 2.44</td>
</tr>
</tbody>
</table>

### Table 4. 10 Second Step Test in Each Gender and Each Generation of Controls

<table>
<thead>
<tr>
<th>Generation</th>
<th>Male</th>
<th>Female</th>
<th>P (Mann-Whitney U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20–29</td>
<td>21.9 ± 2.6</td>
<td>20.6 ± 3.5</td>
<td>P &lt; 0.0001</td>
</tr>
<tr>
<td>30–39</td>
<td>21.4 ± 3.7</td>
<td>20.9 ± 4.4</td>
<td>NS</td>
</tr>
<tr>
<td>40–49</td>
<td>20.9 ± 3.5</td>
<td>19.9 ± 2.2</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>50–59</td>
<td>19.9 ± 3.1</td>
<td>19.0 ± 2.7</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>60–69</td>
<td>18.3 ± 2.8</td>
<td>18.2 ± 2.2</td>
<td>NS</td>
</tr>
<tr>
<td>70–79</td>
<td>17.5 ± 3.1</td>
<td>16.9 ± 2.3</td>
<td>NS</td>
</tr>
<tr>
<td>Average</td>
<td>20.0 ± 3.5</td>
<td>19.2 ± 3.3</td>
<td>P &lt; 0.0001</td>
</tr>
</tbody>
</table>
The test was proven to be quantifiable, reproducible and reliable in repeated trials. However, it was not easily performed in the outpatient department or hospital room because the test usually requires adequately scheduled time, wide space, and an additional measurer.

Preferable assessment of neurologic impairment is objective, quantitative, and easy-to-use. High variability between patients is desirable for a scale that will be sensitive to perioperative change. The ratio of preoperative SD/mean (i.e., coefficient of variation) for the step test (0.51) was greater than for G and R test (0.40) and the JOA score (0.27), suggesting that the step test could be a better measure of clinical improvement. The value of healthy volunteers was 0.17 in step test.

The overall sensitivity to change is well demonstrated for the step test, which shows an improvement after surgery beyond the patient’s selfassessment of motor function of the lower extremities classified in the JOA score. Furthermore, the quantitative nature of the step test data allows a more detailed comparison with control data. It is apparent that, despite the significant improvement after surgery, values for the step test did not reach normal levels.

Usually these functional tests are affected not only by the severity of locomotor disability but also age-related decline. There were some differences between healthy controls in their 20s and 70s in this test. There was a significant negative correlation between the step test and age in normal controls. The ability to correct for the effect of age on the step test could allow extra sensitivity for low levels of locomotor disability that other classification would categorise as normal. The mean value and SD of the step test in 1204 controls is 19.6 and 3.4, respectively. A test result of less than 12.8 (average–2SD) indicates the possibility of cervical compressive myelopathy, if no other locomotor disorders are present. This value might be used as a screening test for cervical compressive myelopathy.

There are many styles of stepping. In this study, we employed the mode of step by lifting the thighs parallel to the floor (hip and knee joints in 90° flexion) in the same place. To keep uniformity among examiners and reproducibility in different trials of same person, the style of test was predetermined.

One of the limitations in this study is that the patients with severe gait disturbances cannot perform this test and their results were estimated to be zero. This test can estimate locomotor...
tor function of trunk and bilateral lower extremities, but can not assess the laterality of symptomatic severity, as the G and R test does. The other limitation is that the step test can be impaired by other medical conditions, such as locomotor disorders. In this test, patients with cerebral palsy, rheumatoid arthritis, thoracic myelopathy, lumbar spinal stenosis, and hip or knee osteoarthritis were excluded. The patients with tho-racic myelopathy have a possibility of demonstrating similar data as the patients with cervical compressive myelopathy. Thus, the use of the step test for thoracic myelopathy is under investigation.

Data obtained from the step test may indicate the viability of the spinal cord and predict the reversibility of impaired function, because worsening of performance on the test indicates damage to the long tracts of the spinal cord. More the damage present to the long tracts, the less likely it is to be reversible; however, further study is needed to verify this.

**Conclusion**

A 10 second step test is an easily performed, quantitative task, and is useful in assessing the severity of CSM. This test is reproducible and comprehensively performed worldwide and is not affected by the difference in language and life style. Moreover, it can be used for determining the effects of decompressive surgical treatment.

**Key Points**

- A 10 second step test was developed as a quantifiable measure of severity in cervical compressive myelopathy.

- The number of steps was significantly lower in patients than in control and decreased with age in both groups.
- Number of steps significantly correlated with the number of G and R, walking grade of JOA scores, and total JOA score.
- One hundred twenty-three patients were retested at 12 months after surgery and showed significant postoperative improvement in this test.

**Acknowledgment**

The authors thank Mr. Nakayama (PT) for his work, collecting the data of 1204 normal.

**References**