A simple performance test for quantifying the severity of cervical myelopathy

N. Hosono, H. Sakaura, Y. Mukai, T. Kaito, T. Makino, H. Yoshikawa

From Osaka Kosei-nenkin Hospital, Osaka, Japan

We evaluated 30 patients with cervical myelopathy before and after decompressive surgery and compared them with 42 healthy controls. All were asked to grip and release their fingers as rapidly as possible for 15 seconds. Films recorded with a digital camera were divided into three files of five seconds each. Three doctors independently counted the number of grip and release cycles in a blinded manner (N1 represents the number of cycles for the first five-second segment, N2 for the second and N3 for the third). N2 and N3 of the pre-operative group were significantly fewer than those of the control group, and the post-operative group’s results were significantly greater than those of the pre-operative group. In the control group, the numbers decreased significantly with each succeeding five-second interval (fatigue phenomenon). In the pre-operative myelopathy group there was no significant difference between N1 and N2 (freezing phenomenon).

The 15-second test is shown to be reliable in the quantitative evaluation of cervical myelopathy. Although it requires a camera and animation files, it can detect small changes in neurological status because of its precise and objective nature.

The outcome of patients with a compressive myelopathy can be measured using various scales of severity, such as that of Nurick,1 Harsh et al2 and Cooper and Epstein,3 or the Japanese Orthopaedic Association (JOA) score.4,5 However, these are of low sensitivity, with few and generally arbitrary categories, any of which may cover a large range of severity. In addition, a subjective scale based on patients’ symptoms may be coloured by their general psyche and how urgently they feel the need for treatment. Objective measures are needed to make a proper assessment of surgical treatment.

A simple quantitative walking test was proposed by Singh and Crockard,6 but this needs space; also, the test has limited value, not only for mildly affected patients, whose walking is often normal, but also for those most severely affected, who cannot walk unaided.

It is well known that finger clumsiness precedes other weaknesses in myelopathy.7 Ono et al7,8 proposed a performance test which measures the number of finger grips and releases performed as fast as possible in ten seconds. Although the test is simple and requires only a watch with a second hand, it is not widely used, mainly because its reliability has not been validated. In order to establish the reliability of the test and to facilitate repeated and objective evaluation of finger movement, we recorded finger movements with a digital camera, and extended the test to 15 seconds to allow possible changes of movement to be observed over three five-second intervals.

Patients and Methods

We studied 30 patients, all with MRI evidence of cervical cord compression who had been admitted for decompressive surgery and used 42 patients admitted for hip or knee joint replacement as a control group. No patient had previous history or symptoms of a cervical disorder, nor any systemic disease such as rheumatoid arthritis or cerebral palsy. First, with their right palm pronated, each patient was asked to fully grip and release their fingers as fast as possible. This was then repeated with the left hand. The movements were recorded from an anterolateral direction by a digital camera (DSC-F505V, Sony Corp., Tokyo, Japan) in ‘movie’ mode. The recording began from the second grip to avoid the motion lag from the cue to the start of movement. The field of view was restricted to the hand and forearm, so that the recordings could be evaluated blindly at a later date. In the myelopathy group the test was performed pre-operatively and then repeated every two weeks after a unilateral opening laminoplasty,9 which achieved successful decompression on
Table I. The intraclass correlation coefficient (ICC) and 95% confidence interval (95% CI) for each phase of the 30 myelopathy patients

<table>
<thead>
<tr>
<th></th>
<th>Right hand</th>
<th>Left hand</th>
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<tbody>
<tr>
<td><strong>Pre-operative (s)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 5</td>
<td>0.995 (0.989 to 0.998)</td>
<td>0.991 (0.983 to 0.996)</td>
</tr>
<tr>
<td>5 to 10</td>
<td>0.996 (0.992 to 0.998)</td>
<td>0.993 (0.986 to 0.996)</td>
</tr>
<tr>
<td>10 to 15</td>
<td>0.986 (0.973 to 0.993)</td>
<td>0.990 (0.979 to 0.995)</td>
</tr>
<tr>
<td><strong>Post-operative (s)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 5</td>
<td>0.991 (0.982 to 0.996)</td>
<td>0.991 (0.984 to 0.996)</td>
</tr>
<tr>
<td>5 to 10</td>
<td>0.992 (0.985 to 0.996)</td>
<td>0.979 (0.961 to 0.990)</td>
</tr>
<tr>
<td>10 to 15</td>
<td>0.987 (0.975 to 0.994)</td>
<td>0.982 (0.964 to 0.991)</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>0.988 (0.979 to 0.996)</td>
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MRI in all cases. The control group performed the test before their arthroplasty.

From the original movie file, five-second segments were abstracted individually by a technician (TM) to create a first, second and third file. Each was slowed to half speed and numbered randomly using a computer-generated random table. As right and left finger movement were recorded separately there were 360 (2 × 3 × 30 × 2) five-second files for the myelopathy group and 252 (2 × 3 × 42 × 1) for the control group. These 612 files were evaluated independently in a blinded manner by three experienced spinal surgeons (NH, HS, YM). The number of grip and release cycles was counted in increments of 0.5, from a fully open to a fully closed hand, or vice versa. For each five-second file, the average of the three examiners’ numbers was used, with N1 representing the average number of grip and release cycles for the first file, N2 for the second and N3 for the third. The total number of grip and release cycles over 15 seconds (N) was the sum of N1, N2 and N3. The patients’ neurological status was evaluated using the JOA score pre-operatively and two weeks post-operatively, and the correlation of their JOA scores with the sum of their right and left grip cycles was analysed. The protocol was approved by the institutional review board of the hospital and informed consent was obtained from all patients.

The inter-observer reliability of the 15-second test was examined by determining the intra-class correlation coefficient10 and 95% confidence interval (CI)11 using data obtained from the pre- and post-operative myelopathy patients. The data were divided according to the time of recording, laterality and phase (first, second, and third five-second segments), so that they could be studied independently. All analyses were performed using SAS 9.1 (SAS Institute Inc., Cary, North Carolina).

Results
The inter-observer reliability of counting the number of grip and release cycles was high (intra-class correlation coefficient 0.989 (95% CI 0.979 to 0.996), Table I). All values are reported as a mean and SD. The overall N was 32.5 (SD 9.0) in the control group, 22.9 (SD 8.7) in the pre-operative myelopathy group, and 34.9 (SD 7.6) in the post-operative myelopathy group. It was significantly lower in the pre-operative group than in the control group (t-test, p < 0.0001) and significantly greater in the post-operative than in the pre-operative group (paired t-test, p < 0.0001). There was no significant difference in N between the control and post-operative groups (t-test, p = 0.07). N1, N2 and N3 were 11.3 (SD 3.3), 10.9 (SD 3.1) and 10.4 (SD 2.8), respectively in the control group; 7.8 (SD 3.1), 7.7 (SD 3.0) and 7.4 (SD 2.7), respectively in the pre-operative group; and 12.0 (SD 2.8), 11.8 (SD 2.5) and 11.2 (SD 2.3), respectively in the post-operative group. The values of N1, N2 and N3 were significantly lower in the pre-operative than in the control group (t-test, p < 0.0001) and significantly greater in the post-operative than in the pre-operative group (paired t-test, p < 0.0001, Fig. 1).

In the control group, N2 was significantly lower than N1, and N3 was also significantly lower than N2 (paired t-test, Bonferroni adjustment, p < 0.0001, Fig. 2). This indicates a significant reduction in the number of cycles in each successive five-second period and appears to be the result of finger fatigue. Conversely, in the pre-operative myelopathy group, N1 and N2 were not significantly different (paired t-test, Bonferroni adjustment, p = 0.15), whereas N3 was significantly lower than N2 (paired t-test, Bonferroni adjustment, p = 0.0002, Fig. 3). The lack of a significant difference between N1 and N2 seems to indicate that, at the beginning of the test, myelopathy patients cannot open or close their fingers at their maximum velocity, as though their fingers are frozen. However, in the post-operative myelopathy group the fatigue phenomenon occurred between N1 and N2 (paired t-test, Bonferroni adjustment, p < 0.0001), as well as between N2 and N3 (paired t-test, Bonferroni adjustment, p = 0.0143), similar to the control group (Fig. 4).

In the myelopathy group, the JOA score improved significantly from 10.2 (SD 2.7) pre-operatively to 14.2 (SD 2.1) (paired t-test, p < 0.0001) post-operatively, with no patients deteriorating thereafter. There was a significant positive
correlation between the JOA score and the sum of the right and left Ns (Pearson’s correlation coefficient 0.715, $p < 0.0001$, Fig. 5).

**Discussion**

Ono et al.\(^8\) noted that healthy subjects could complete more than 20 grip and release cycles in 10 seconds. Although the test exclusively assesses finger movement, some authors have indicated a significant correlation between the results of this test and other disease severity scales, which evaluate not only motor but also sensory functions in the extremities and trunk.\(^{12,13}\) In this study, there was significant correlation between the 15-second test and the JOA score ($r = 0.715$). This can be explained by the fact that most
JOA score parameters are associated with a pyramidal tract disorder of the spinal cord, which includes impaired finger movement. As a method for evaluating myelopathy, the ten-second test has advantages over scoring systems. It can be done anywhere, at any time, whereas scoring systems require an experienced rater to improve their reliability. Furthermore, the ten-second test is a reproducible, quantitative assessment, whereas scoring systems are semi-quantitative, with no statistical basis for the points assigned to each section. The ten-second test can be done hourly to detect slight changes in neurological status; consequently, a patient's daily worsening pre-operatively or improvement post-operatively can be evaluated in detail. Despite these merits, the reliability of the ten-second test has not been statistically validated, thus it is not widely used. In this study, we demonstrated the high reliability of the video-recorded 15-second test, with an inter-observer intra-class correlation coefficient of 0.989. At the beginning or end of each five-second segment, the patients' fingers were usually between the fully closed and the fully opened positions. Although an inter-observer difference could occur depending on whether the observer considered the fingers to be open or closed, the reliability of the test has been proven statistically.

In healthy controls, the number of cycles decreased every five seconds. This is considered to be because of fatigue caused by the maximal effort required. Conversely, the fatigue phenomenon was not observed between the second and second segments in myelopathy patients pre-operatively, although there was fatigue between the second and third segments. The reduced number of grip and release cycles in the first five seconds was not due to a time lag between the cue and beginning of movement, as the recording was from the second grip. Myelopathy patients could not open or close their fingers with their maximum velocity at the beginning of movement, as though their fingers were frozen. Ishida et al reported that the walking velocity of myelopathy patients was significantly lower over the first three metres than the last three when they were asked to walk 30 m, as required in the walking test of Singh and Crockard. It is interesting that ‘freezing’ or clumsiness during the initial phase of movement was seen in the upper and lower extremities of myelopathy patients. However, after successful decompression, they showed no ‘freezing’. The video-recorded 15-second test is shown to be a reliable method which can quantitatively evaluate the severity of cervical myelopathy. Although the test is less practicable than the ten-second test, and requires a digital camera and animation files, it can detect small changes in neurological status because of its precise and objective nature.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References