Correlations and time-dependent changes of upper arm performance tests, the Japanese Orthopaedic Association score, and a newly developed patient-based outcome measure

THE JAPANESE ORTHOPAEDIC CERVICAL MYELOPATHY QUESTIONNAIRE

Aims
In this prospective observational study, we investigated the time-dependent changes and correlations of upper arm performance tests (ten-second test and Simple Test for Evaluating Hand Function (STEF), the Japanese Orthopaedic Association (JOA) score, and the JOA Cervical Myelopathy Evaluation Questionnaire (JOACMEQ) in 31 patients with cervical myelopathy who had undergone surgery.

Patients and Methods
We hypothesised that all the indices correlate with each other, but show slightly different recovery patterns, and that the newly described JOACMEQ is a sensitive outcome measure.

Results
Peak recoveries were achieved one month post-operatively in the ten-second test and JOACMEQ upper extremity function (UEF) subscale, and at three months in the JOA and STEF scores. The recoveries of all indices were maintained until six months post-operatively. The upper extremity function (UEF) subscale in the JOACMEQ showed the strongest correlation with STEF although all the indices correlated with each other. Patients with $\geq 20$ and $< 20$ acquired points in the UEF subscale were classified into the UEF-improved and UEF-unimproved groups. Comparisons between the groups showed that pre-operative evaluation of “coordinated motion” of the STEF was significantly low in the UEF-unimproved group.

Conclusion
These results indicate that the JOACMEQ is a concise, sensitive, patient-based outcome measure for evaluating functional recovery in patients with cervical myelopathy who have undergone surgery.

A number of grading scales have been developed for evaluating cervical myelopathy. These include systemic outcome assessments, upper arm performance tests and patient-based quality of life (QOL) outcome measures. The Japanese Orthopaedic Association (JOA) or modified JOA score, which focus on neurological function, are commonly used. They have better sensitivity and specificity than other outcome measures.

Several upper arm performance tests such as the ten-second test and the Simple Test for Evaluating Hand Function (STEF) have been reported to correlate with the JOA score. As recent studies have emphasised clinical results based on patient-based outcome measures, a patient-based QOL outcome measure, the Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ), was described in 2009. It was designed to overcome the limitations of the physician-based JOA score by adding assessments of patient satisfaction, function and general health. The JOACMEQ has been reported to correlate with the JOA score in patients with cervical myelopathy.

However, these indices have not been investigated together and their correlations have not been analysed.

The purpose of this observational study was to investigate prospectively the time-dependent changes of the upper arm performance tests (ten-second test and STEF), JOA score and JOACMEQ, and to investigate the correlations...
among each in patients with cervical myelopathy who had undergone surgical treatment.

Our hypotheses were that: all the indices correlate with each other; the simple upper arm performance test (ten-second test) or questionnaires for upper extremity function indicate recovery at an early stage; comprehensive outcome measures (the JOA score) present slightly slow recovery, and the newer JOACMEQ is a concise and sensitive outcome measure that can serve as a substitute for the complex STEF.

**Patients and Methods**

A total of 42 consecutive patients underwent surgery for cervical myelopathy between 2011 and 2012. Four with rheumatoid arthritis and seven who were not able to complete the questionnaires were excluded, leaving 31 in the study. There were ten women and 21 men with a mean age of 60.9 years (30 to 81). The Upper extremity function in the JOA score (JOA UEF; four-point system) present slightly slow recovery, and the newer JOACMEQ is a concise and sensitive outcome measure that can serve as a substitute for the complex STEF.

### Table I. The demographics of the patients, presented as mean (standard deviation, SD) (range)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Patients (n = 31)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>60.9 (SD 13.0) (30 to 81)</td>
</tr>
<tr>
<td>Gender (male:female)</td>
<td>21:10</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>24.5 (SD 3.6) (19.3 to 34.5)</td>
</tr>
<tr>
<td>Disease</td>
<td>CSM: 23, CDH: 3, OPLL: 5</td>
</tr>
<tr>
<td>Pre-operative JOA score (17-point system)</td>
<td>10.7 (SD 2.0)</td>
</tr>
<tr>
<td>Pre-operative JOA UEF (4-point system)</td>
<td>2.5 (SD 0.7)</td>
</tr>
<tr>
<td>Pre-operative 10-second test (times)</td>
<td>Dominant hand: 19.1 (SD 5.6) Non-dominant hand: 21.8 (SD 6.3)</td>
</tr>
<tr>
<td>Pre-operative STEF score</td>
<td>Dominant hand: 89.9 (SD 15.2) Non-dominant hand: 91.9 (SD 15.8)</td>
</tr>
<tr>
<td>Operation</td>
<td>Laminoplasty: 26 Laminoplasty + Posterior lateral fusion: 1 Anterior fusion: 4</td>
</tr>
</tbody>
</table>

CSM, cervical spondylotic myelopathy; CDH, cervical disc herniation; OPLL, cervical ossification of posterior longitudinal ligament

### Results

The demographics of the patients are shown in Table I. The aetiology of cervical myelopathy was spondylotic myelopathy in 23 patients, disc herniation in three, and ossification of the posterior longitudinal ligament in five patients. **Time-dependent changes of all the indices.** There was a significant improvement in JOA UEF at POW1, in the UEF extremity function (UEF); lower extremity function; bladder function; and QOL, with higher scores indicating better maintenance of QOL (100-point system). In this study, according to the methods of analysing the data for the JOACMEQ, patients with ≥ 20 and < 20 acquired points in the UEF subscale were classified into UEF-improved and UEF-unimproved groups, respectively.

The clinical endpoints were: the time-dependent changes of all indices, the correlations between the STEF scores and other indices, the correlations between the JOACMEQ UEF subscale and the three categories of the STEF and comparisons of the time-dependent changes in the STEF scores in the three categories between the UEF-improved and UEF-unimproved groups of the JOACMEQ. Details of complications that occurred within six months after surgery were also collected. The study was approved by the Ethics Review Board of our hospital (No. 26-2), and informed consent was obtained from all patients.

### Statistical analysis

This was undertaken using StatView for Windows version 5.0 (SAS Institute, Cary, North Carolina). The Wilcoxon signed-rank test was used to compare the peri-operative scores for each patient, and the Mann-Whitney’s U test to compare the peri-operative scores between the UEF-improved and UEF-unimproved groups. The JOA score, ten-second test, STEF score and the subscale of UEF in JOACMEQ were compared using Spearman’s rank correlation coefficient. A power study indicated that a sample size of 42 patients would be required to reduce the chances of a type 1 error at a two-sided p-value < 0.05 in this study. The level of significance was set at p < 0.05 and the coefficient of correlation value (r) at > 0.4.
subscale of JOACMEQ at POM1, in the ten-second test at POW1, and in the STEF at POM1. Post-operative peak recoveries were achieved at POM3 in the JOA UEF (Fig. 1a), at POM1 in the UEF subscale of JOACMEQ (Fig. 1b), at POM1 in the ten-second test (Fig. 1c), and at POM3 in the STEF score (Fig. 1d). Peak recovery indicates the time points when the maximal value was marked. The recoveries of all indices were maintained until POM6. In each category of the STEF, there were significant improvements at POM1, and the recoveries of all categories were maintained until POM6 (Fig. 2).

The probability values and correlation coefficients for all indices are shown in Table II. There were moderate correlations between the JOA UEF and the JOACMEQ UEF ($r = 0.345, p = 0.064$) and between the ten-second test and the JOACMEQ UEF in both hands. There was strong correlation between the ten-second test and the STEF score in the dominant right hand ($r = 0.309, p = 0.006$). Moreover, the JOACMEQ UEF showed moderate correlations with all the other indices and a significant strong correlation with the STEF score (dominant (D) hand: $r = 0.835, p = 0.005$; non-dominant (ND) hand: $r = 0.754, p = 0.007$). Strong correlations were also found between the STEF score in all categories and the UEF subscale in JOACMEQ (Table III).

Comparisons between the UEF-improved and UEF-unimproved groups for the STEF scores in all categories are shown in Figure 3 (right hand) and Figure 4 (left hand). There were significant improvements in all three categories of the STEF at POW1 in the UEF-improved group. Conversely, there was no significant improvement in any of the indices in the UEF-unimproved group. In both hands, the STEF score in all three categories in the UEF-unimproved group was significantly lower than that in the UEF-improved group post-operatively. In the non-dominant hand, the STEF score in the category of “coordinated motion” at POM6 had the biggest effect on the improvement of the JOACMEQ UEF. Comparisons between the UEF-improved and UEF-unimproved groups for the ten-second test are shown in Figure 5. There were significant improvements at POW1 only in the UEF-improved group in both hands. While the pre-operative ten-second test and the STEF scores in the categories “grip motion” and “pinch motion” were not significantly different between the groups, the pre-operative STEF score in the category of
“coordinated motion” was significantly different between the groups in both hands \((p < 0.01)\).

There were two surgical site infections and two patients had a transient C5 palsy. One patient with C5 palsy in the dominant hand fully recovered at POW1, and the other with a palsy in the non-dominant hand fully recovered at POM3. An additional posterior fusion was performed in one patient with delayed union after anterior fusion. Hence, overall, complications occurred in five patients \((16.1\%)\).

**Discussion**

The results supported our hypothesis that all the indices correlate with each other, and the simple upper arm performance test (ten-second test) and UEF recover at early stage, and a comprehensive outcome measure (the JOACMEQ) and performance test (the STEF score) have a slightly slower recovery.

Peak recoveries were achieved at POM1 in the ten-second test and the JOACMEQ UEF, and at POM3 in the JOA and STEF scores. The recoveries of all indices were
maintained until POM6. Analysis of the correlation for all indices showed that there were significant correlations between the JOACMEQ UEF and the other indices, with the strongest correlation between the JOACMEQ UEF and the STEF score. These results support another hypothesis that the newly described JOACMEQ is a concise and sensitive outcome measure.

The difference in the recoveries between the outcome measures may reflect the different pathological conditions that each outcome measure represents. For example, the
early recovery of the ten-second test might suggest that paralysis of the fingers, or clumsiness in compressive myelopathy, is caused by circulatory disorders in the spinal cord, which can recover immediately following decompression. Chronic pressure on the spinal cord and vascular structures causes slow but progressive demyelination and ischaemia, with associated symptoms that vary according to the location and degree of damage to the cord.

The analyses among all indices showed that there were significant correlations between the JOACMEQ UEF subscale and the other indices, with the strongest correlation being with the STEF score, especially, the category of “coordinated motion”. Although the correlations between the STEF score and the ten-second test were not so high (0.211 to 0.309), we speculate that minimal changes in grip motion in the STEF weakened the correlation because myelopathy affects extension of the fingers rather than flexion and “coordinated motions”. Another reason could be the late recovery in STEF and JOA (POM1) UEF compared with the ten-second test (POW1). These factors may affect the degree of the linear correlation.

On the other hand, although a significant correlation was found between the ten-second test and the “coordinated motion” in the STEF score, only a slight, non-significant correlation was found between the JOA UEF and the STEF score. STEF was originally developed for the quantitative assessment of the function of the hand in patients with brain disorders, but has since also been used to assess functional recovery in patients with cervical myelopathy. Although a major strength of the STEF score is that it enables detailed evaluation of UEF, its biggest weakness is that it is very time consuming. The fact that the UEF-improved group pre-operatively, and at all time points except at POM6. However, there were no significant improvements in the UEF-unimproved group. The STEF score of the category for “coordinated motion” in the UEF-improved group was significantly lower than that in the UEF-improved group pre-operatively, and at all time points post-operatively. These results suggest that the pre-operative use of the STEF can be a predictor of post-operative functional recovery.

One limitation of this study is the sample size. A power analysis indicated that 42 patients would be required to reduce the chances of a type 1 error at a two-sided p-value < 0.05 in this study. Unfortunately, 11 patients were excluded from the analysis by various reasons although we initially enrolled 42 patients. However, the fact that the significant differences were demonstrated in our analysis of 31 patients means that we could demonstrate strong significant correlations between the indices.

In conclusion, this prospective study of the correlations and the time-dependent changes of the upper arm performance tests, JOA score, and JOACMEQ in patients with cervical myelopathy, who are surgically treated, showed both correlations among the indices and slight difference in the timing of post-operative peak recoveries. The newly developed JOACMEQ showed the strongest correlation with the STEF score and was found to be a concise and sensitive patient-based QOL outcome measure for evaluating functional recovery in these patients.

## Table II. Correlation analyses for all the indices

<table>
<thead>
<tr>
<th>Correlation</th>
<th>JOA UEF</th>
<th>ten-second test: D</th>
<th>ten-second test: ND</th>
<th>UEF in JOACMEQ</th>
<th>STEF: D</th>
<th>STEF: ND</th>
</tr>
</thead>
<tbody>
<tr>
<td>ten-second test: D</td>
<td>r = 0.146; p = 0.425</td>
<td>r = 0.101; p = 0.371</td>
<td>r = 0.345; p = 0.064</td>
<td>r = 0.150; p = 0.664</td>
<td>r = 0.127; p = 0.209</td>
<td></td>
</tr>
<tr>
<td>ten-second test: ND</td>
<td>r = 0.101; p = 0.371</td>
<td>r = 0.329; p = 0.232</td>
<td>r = 0.309; p = 0.006</td>
<td>r = 0.150; p = 0.664</td>
<td>r = 0.127; p = 0.209</td>
<td></td>
</tr>
<tr>
<td>UEF in JOACMEQ</td>
<td>r = 0.345; p = 0.064</td>
<td>r = 0.329; p = 0.023</td>
<td>r = 0.306; p = 0.016</td>
<td>r = 0.835; p = 0.005</td>
<td>r = 0.754; p = 0.007</td>
<td></td>
</tr>
<tr>
<td>STEF: D</td>
<td>r = 0.101; p = 0.371</td>
<td>r = 0.329; p = 0.232</td>
<td>r = 0.309; p = 0.006</td>
<td>r = 0.150; p = 0.664</td>
<td>r = 0.127; p = 0.209</td>
<td></td>
</tr>
<tr>
<td>STEF: ND</td>
<td>r = 0.345; p = 0.064</td>
<td>r = 0.329; p = 0.023</td>
<td>r = 0.306; p = 0.016</td>
<td>r = 0.835; p = 0.005</td>
<td>r = 0.754; p = 0.007</td>
<td></td>
</tr>
</tbody>
</table>

JOA, Japanese Orthopaedic Association; JOACMEQ, JOA Cervical Myelopathy Evaluation Questionnaire; STEF, Simple Test for Evaluating Hand Function; UEF, upper extremity function; D, dominant hand; ND, non-dominant hand

## Table III. Correlation between the each category of Simple Test for Evaluating Hand Function and JOACMEQ UEF

<table>
<thead>
<tr>
<th>Grip motion (D)</th>
<th>Grip motion (ND)</th>
<th>Pinch motion (D)</th>
<th>Pinch motion (ND)</th>
<th>Coordinated motion (D)</th>
<th>Coordinated motion (ND)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UEF in JOACMEQ</td>
<td>r = 0.869; p = 0.007</td>
<td>r = 0.764; p = 0.008</td>
<td>r = 0.858; p = 0.002</td>
<td>r = 0.765; p = 0.033</td>
<td>r = 0.700; p = 0.022</td>
</tr>
</tbody>
</table>
| JOACMEQ, Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire; UEF, upper extremity function; D, dominant hand; ND, non-dominant hand
Take home message:
The newly invented patient-based outcome measure for cervical myelopathy (JOACMEQ) is a concise and sensitive outcome measure.

Supplementary material
Tables showing the evaluation items in m-JOA score and questionnaires in JOACMEQ are available alongside the online version of this article at www.bjj.bone-andjoint.org.uk

Author contributions:
H. Fujiwara: Design of the study, Data collection and analysis, Paper writing.
T. Makino: Data collection and analysis.
K. Yonenobu: Review of the manuscript and feedback.
H. Honda: Data collection and analysis.
T. Kaito: Study idea and design, Writing the paper, Review of the manuscript and overview of the study.

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.

This article was primary edited by J. Scott and first proof edited by A. C. Ross.

References