Validity of the 10-s step test: prospective study comparing it with the 10-s grip and release test and the 30-m walking test

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Abstract Cervical compressive myelopathy (CCM) is one of the common neurological disorders seen in the geriatric population. The 10-s Grip and Release (“G and R”) Test and the 30-m Walking (“Walking”) Test are widely known as quantifiable physical assessments for the severity of cervical myelopathy. We developed the 10-s Step (“Step”) Test as another easily performable quantifiable measure for this. However, it is not clear if the Step test can adequately reveal the severity of myelopathy like the other established tests, given its simple method. The purpose of this study was to verify the practical effectiveness of this Step Test as a quantifiable parameter of CCM in comparison with the other two established tests. 168 consecutive patients with CCM were selected. Only 101 patients having >12-month postoperative follow-up were included. All were treated with cervical expansive laminoplasty. The three above mentioned quantitative tests and two assessment questionnaires (Japanese Orthopedic Association [JOA] Score, and lower-limb-function section of the Japanese Orthopedic Association cervical myelopathy evaluation questionnaire [JOACMEQ-L]) for CCM were prospectively administered, and the results of the

three tests were evaluated using linear regression models to determine which quantitative test best reflected the results of the JOA score and JOACMEQ-L. Each quantitative test was carried out twice, just before and 1 year after surgery. The intraobserver reproducibility of the 10-s Step Test was found to be as high as that of the other tests both before and after surgery. Linear regression analyses showed that the results of the Step Test correlated with JOA scores to the same degree as the Walking Test results did, and to a greater degree than the G and R Test results did. Moreover, the results of the Step Test showed a significant degree of correlation with JOACMEQ-L. In view of these findings, our conclusion was that the easily performed Step Test is an useful test for assessing the severity of cervical myelopathy, especially for the lower limb dysfunction secondary to CCM.

Keywords Cervical myelopathy · Assessment · Physical test · Objective · Quantitative

Introduction

Cervical compressive myelopathy (CCM) is a neurologic disorder commonly seen in the elderly. There are many causes of CCM, including spondylosis, disk herniation, and ossification of the posterior longitudinal ligament. Patients’ symptoms include weakness and clumsiness of hands, hand paresthesia, gait disturbances, and urinary incontinence [2, 10]. However, the assessment of myelopathy can be difficult especially early in the course of the disease, because of its insidious progression [1].

In cases of severe compression or progressive course, the accepted treatment for CCM is usually surgical decompression. To determine the best stage for surgical

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intervention and compare the outcomes in different treatment strategies, a detailed clinical examination should always be performed in combination with supplemental assessment methods.

A number of classification systems for myelopathy have been developed, such as the Nurick Grade [7], Ranawat Scale [9], and Japanese Orthopedic Association (JOA) Score [6]. The Japanese Orthopedic Association cervical myelopathy evaluation questionnaire (JOACMEQ) was also recently created as a patient self-completed questionnaire to evaluate CCM [3–5]. However, these measures are quantitatively insufficient, and have very few and largely arbitrary evaluation categories.

Besides these classification systems, there are some clinical tests, such as the 10-s Grip and Release (“G and R”) Test [8] and the 30-m Walking (“Walking”) Test [11]. Together with the classification systems, they comprise the hitherto existing quantitative and objective methods to evaluate cervical myelopathy.

However, the results of the G and R Test reflect not only long tract symptoms but also segmental and radicular symptoms. Therefore, this method might not be suitable for the evaluation of pure myelopathy. On the other hand, while the Walking Test was reported to be a reproducible and reliable test for myelopathy evaluation, it is not easily performed.

To address the lack of an easily performable evaluation test for myelopathy, we developed the 10-s Step (“Step”) Test [12]. However, it was not clear whether the Step Test could adequately reveal the severity of myelopathy, given such a short performance time and simple method. We therefore undertook this study to confirm the actual usefulness of the Step Test as a quantifiable parameter of CCM in comparison with the other two established tests.

Materials and methods

Subjects

A total of 168 patients with CCM were enrolled prospectively with their approval from January to December 2008. Due to some patients’ clinical histories and symptoms, the decision was made to exclude them from the study: a total of 40 patients with cerebral palsy, rheumatoid arthritis, hip or knee osteoarthritis, or other spinal diseases, as well as those with traumatic cervical cord injury, were excluded. An additional 27 patients, while indistinguishable in terms of symptoms from the others included in the study, became unavailable for postoperative follow-up within the 12 months after surgery due to various personal problems unrelated to their CCM. The remaining 101 patients who

could be tracked for more than 12 months post-operation were included in this study. There were 61 men and 40 women, and the mean age was 63.6 ± 11.8 years (range 16–87 years). The diagnosis was confirmed by both neurological examination and imaging studies such as magnetic resonance imaging and a computed tomography myelogram. The primary pathology in these CCM cases was cervical spondylotic myelopathy in 87 and ossification of the posterior longitudinal ligament in 14 patients. Expansive laminoplasty was performed in all the patients (C3–7, 86 cases; C2–7, 7 cases; C3–6, 3 cases; C4–7, 3 cases; and C2–T1, 2 cases).

Clinical tests

The patients performed the G and R, Walking, and Step Tests. Preoperatively, the Walking Test could not be performed by three patients with walking difficulties. All the patients were provided with information regarding the three tests before examination. All tests were assessed twice on one day by physical therapists before surgery and 1 year after surgery. Intraobserver reliability of the tests was evaluated, and the mean for the data was used for regression analysis.

G and R test [8]

The patient is asked to grip and release with the fingers as rapidly as possible with the arm kept in the same position. The number of complete cycles of movement within 10 s is counted; it has been reported that normal adults can perform such rapid grip and release movements more than 20 times in 10 s.

Walking test [11]

The patients walk on a smooth flat surface over a ward corridor for a measured 30 m distance (15 m in one direction and back with one turn). The time taken was recorded with a stopwatch and the number of steps taken was counted. The patients were requested to walk at maximum comfortable speed (with any normally used walking aids).

Step test [12]

The patients were asked to take high steps by bending their knee at 90°, making their thighs parallel, or in line with, the floor. They were asked to make these steps in the same place, without holding on to anything for balance, and make as many steps as they could in 10 s. If the patients seemed to be at risk of falling, the test was done close to a hand bar that could be grabbed onto for balance.

JOA score and JOACMEQ-L

The JOA score (Table 1) and information in the lower-limb-function section of the JOACMEQ (JOACMEQ-L, Table 2) were evaluated before and 1 year after surgery. JOACMEQ [3–5] is a patient-based evaluation method for CCM comprising 24 question items. Answers are evaluated for five functional areas (cervical spine function, upper limb function, lower limb function, bladder function, and quality of life) based on corresponding domains according to the provided calculating formulas.

Statistical analysis

A standard StatMate (ATMS Co., Ltd., Tokyo, Japan) software package was used for data analysis. The repeatability of two measurements by each test was examined with the statistics from Bland and Altman plot. The associations of G and R, Walking, and Step Tests with JOA score and JOACMEQ-L were evaluated with linear regression models. $P < 0.05$ was considered statistically significant.

Table 1 JOA score

I. Motor function of the upper limb
0. Impossible to eat with chopsticks or spoon
1. Possible to eat with spoon, but not with chopsticks
2. Possible to eat with chopsticks, but inadequate
3. Possible to eat with chopsticks, but awkward
4. Normal
II. Motor function of the lower limb
0. Impossible to walk
1. Needs cane or aid on flat ground
2. Needs cane or aid only on stairs
3. Possible to walk without cane or aid but slowly
4. Normal
III. Sensory function
A. Upper limb
1. Apparent sensory loss
2. Minimal sensory loss
3. Normal
B. Lower limb (same as upper limb)
C. Trunk (same as upper limb)
IV. Bladder function
0. Complete retention
1. Severe disturbance (sense of retention, dribbling, and incomplete continence)
2. Mild disturbance (urinary frequency and hesitancy)
3. Normal

Results

Table 3 shows the repeatability of each test. The average of the difference between two repeated measurements was not substantial in any test. The standard deviation was found to be small enough to be used in a clinical practice.

The results of the three quantifiable physical tests, JOA score and JOACMEQ-L are shown in Table 4. The results of the three physical tests improved postoperatively.

The correlations of the three quantitative clinical tests with JOA score (Table 5) and JOACMEQ-L (Table 6) were analyzed using regression analysis. In the univariate regression for JOA, any test was a significant predictor, but Step Test had a largest R^2 for pre-operation, and Walking Test (time) for post-operation. When a stepwise procedure was applied in multivariate analysis, Step and Walking Tests (steps) were selected for pre-operation and Walking Test (time) for post-operation. While the R^2 was 0.319 for Step and Walking Tests (steps) in pre-operation, it was 0.181 for Walking Test (time) in post-operation. For JOACMEQ-L, the largest R^2 was Step Test both in pre-

Table 2 Lower limb function in the JOA cervical myelopathy evaluation

Calculating formula for lower limb function
$(Q3-1 \times 10 + Q3-2 \times 10 + Q3-3 \times 15 + Q3-4 \times 5 + Q3-5 \times 5 - 45) \times 100 \div 110$
Questionnaire
Q3-1 Can you walk on a flat surface?
1) Impossible
2) Possible but slowly even with support
3) Possible only with the support of a handrail, a cane, or a walker
4) Possible but slowly without any support
5) Possible without difficulty
Q3-2 Can you stand on either leg without the support of your hand? (the need to support yourself)
1) Impossible with either leg
2) Possible on either leg for more than 10 s
3) Possible on both legs individually for more than 10 s
Q3-3 Do you have difficulty in going up the stairs?
1) I have great difficulty
2) I have some difficulty
3) I have no difficulty
Q3-4 Do you have difficulty in one of the following motions: bending forward, kneeling, or stooping?
1) I have great difficulty
2) I have some difficulty
3) I have no difficulty
Q3-5 Do you have difficulty in walking more than 15 min?
1) I have great difficulty
2) I have some difficulty
3) I have no difficulty

Table 3 Repeatability of two measures for the three physical tests before and 1 year after surgery

	Mean		Range		Difference ^a	SD ^a
	1st	2nd	1st	2nd		
G and R test (right hand)						
Pre-operation	16.1	17.0	5–38	6–41	−0.89	1.91
Post-operation	20.1	20.7	7–45	7–43	−0.52	1.74
G and R test (left hand)						
Pre-operation	16.3	16.7	5–39	6–40	−0.46	1.68
Post-operation	20.5	20.5	7–41	7–39	0.02	2.00
Walking test (time)						
Pre-operation	25.2	24.2	10–145	10–145	0.95	1.66
Post-operation	21.8	20.8	10–63	10–58	0.89	1.33
Walking test (steps)						
Pre-operation	48.7	48.3	31–170	30–172	0.46	2.03
Post-operation	44.8	44.1	24–100	20–96	0.62	2.01
Step Test						
Pre-operation	14.0	14.3	0–34	0–29	−0.28	1.04
Post-operation	16.1	16.7	4–28	4–29	−0.55	0.87

^a The average of the difference between the 1st and 2nd measurements, and its standard deviation (SD) from Bland and Altman plot

Table 4 Pre- and post-operative 1 year data in the three physical tests and JOA score and JOACMEQ-L

		Pre-operation	Post-operation	P
G and R test	Affected side	15.8 ± 6.0	19.1 ± 6.4	<0.001
Walking test	Time (s)	23.5 ± 15.4	20.8 ± 7.7	<0.05
	Steps	47.3 ± 16.8	43.9 ± 11.9	<0.01
Step test		14.2 ± 4.7	16.1 ± 4.5	<0.001
JOA score		11.1 ± 2.5	14.1 ± 2.6	<0.001
JOACMEQ-L		82.2 ± 19.6	90.7 ± 13.6	<0.001

Paired *t* test was used in each case

operation and in post-operation. In the multivariate analysis, Step and Walking Tests (steps) were selected for pre-operation ($R^2 = 0.436$), and Step and Walking Tests (time) for post-operation ($R^2 = 0.372$).

Discussion

This study was conducted to validate the clinical effectiveness of the 10-s Step Test as a quantitative test to assess the severity of CCM. This study showed that the results of the Step Test correlated with JOA scores as well as or better than the other two tests' results did. Moreover, the Step Test results significantly associated with those for the JOACMEQ-L than the other two tests. Thus, it can be said that the easily performed Step Test is an useful test for assessing the severity of cervical

Table 5 Regression analysis for JOA score as a dependent variable

Test	Univariate			Multivariate ^a	
	<i>b</i>	<i>P</i>	R^2	<i>b</i>	<i>P</i>
Pre-operation					
G and R test (affected side)	0.206	<0.001	0.24	–	
Walking test (time)	−0.076	<0.001	0.19	–	
Walking test (steps)	−0.068	<0.001	0.20	−0.033	0.031
Step test	0.292	<0.001	0.30	0.228	<0.001
Post-operation					
G and R test (affected side)	0.140	<0.001	0.17	–	
Walking test (time)	−0.115	<0.001	0.18	−0.115	<0.001
Walking test (steps)	−0.073	<0.001	0.17	–	
Step test	0.202	<0.001	0.17	–	

^a A stepwise procedure was used for the independent variable selection; R^2 was 0.319 for pre-operation and 0.181 for post-operation

Table 6 Regression analysis for JOACMEQ as a dependent variable

Test	Univariate			Multivariate ^a	
	<i>b</i>	<i>P</i>	R^2	<i>b</i>	<i>P</i>
Pre-operation					
G and R test (affected side)	2.108	<0.001	0.24	–	
Walking test (time)	−0.983	<0.001	0.32	–	
Walking test (steps)	−0.877	<0.001	0.33	−0.541	<0.001
Step test	3.486	<0.001	0.40	2.230	<0.001
Post-operation					
G and R test (affected side)	1.539	<0.001	0.22	–	
Walking test (time)	−1.384	<0.001	0.31	−0.876	0.003
Walking test (steps)	−0.834	<0.001	0.26	–	
Step test	3.100	<0.001	0.44	1.525	0.007

^a A stepwise procedure was used for the independent variable selection; R^2 was 0.436 for pre-operation and 0.372 for post-operation

myelopathy, especially for lower extremity dysfunction following CCM.

In the patient population older than 55 years, CCM is one of the common causes of spinal cord dysfunction. The characteristic complaints of individuals with CCM include insidious onset, painless paresthesia, and loss of dexterity in their upper extremities, and gait disturbance [2, 10]. In cases of severe compression or progressive course, the accepted treatment for CCM is usually surgical decompression. Neurological assessment is crucial to determine the best stage for surgical intervention.

There have been some physical tests used to detect myelopathy in CCM: hyperreflexia, Babinski's Sign, Hoffman's Sign, Lhermitte's Sign, and others. However,

these tests are not quantitative. To evaluate the severity of CCM objectively, more quantitative ways of evaluation are being suggested.

A variety of classifications are used to quantify neurological impairment, such as the Nurick Grade [7], Ranawat Scale [9], and JOA Score [6]. However, these classifications lack the objectivity necessary in neurological examinations: the grades are determined merely by questioning the patients, and the results might be colored by physicians' opinions or preconceptions. Moreover, such evaluation systems are likely to be less precise, because each category covers a huge range of actual severity.

The JOACMEQ, consisting of 24 question items, was recently established as a patient-based method for evaluating CCM [3–5]. It is hoped that this system will provide a more objective method of evaluation. However, the complexity of evaluation makes it difficult to use.

As indicated above, three quantitative tests now exist for CCM, including our new one: the Grip and Release Test [8], the 30-m Walking Test [11], and our 10-s Step Test [12].

The G and R Test was introduced to evaluate myelopathy of the hand [8]. The results of this test reflect not only long tract symptoms but also segmental and radicular symptoms. This test is generally thought to correlate well with the degree of disability of the upper extremities. When cervical spondylosis is isolated to the C6–7 and C7–T1 spinal levels, the results of this test might be normal.

The Walking Test has been described as a valid, quantitative way of assessing CCM [11]. The distance of 30 m makes it a reproducible and reliable test because there is only slight variation from trial to trial. However, it is not easily performed in the outpatient department or hospital room because of the long walking distance required and the necessity of additional trials. Moreover, in patients with severe myelopathy, the Walking Test is more difficult to perform than the Step Test, as we found in this study.

Because of the lack of easily performable evaluation test for myelopathy, we developed the 10-s Step Test as a simple and quantitative assessment for CCM [12]. In our past study [12], comparing the results of the Step Test in CCM patients with the results for 1200 age-matched normal volunteers (lacking CCM), the discriminative validity of this test was shown. However, it was not clear whether the Step Test could reveal the severity of myelopathy as adequately as the other established tests, given its simple method. In this study, the Step Test was found to significantly correlate with the results of complex JOACMEQ-L, and reflect the severity of CCM, especially as evident from walking difficulty. However, one limitation of this study is that performance of this test can be impaired by other

diseases, such as hip and knee osteoarthritis and rheumatoid arthritis. Another limitation is that there is the risk of a patient with severe myelopathy falling (although there were no instances of this in our experiments), so examiners have to keep this in mind when having subjects perform the test.

All of the above-mentioned quantitative physical tests are confidential objective assessment methods for CCM. When they are combined with clinical tests such as the JOA score or JOACMEQ, even more objective and quantitative evaluation of CCM can be achieved. The 10-s Step Test, however, not only is useful for assessing the severity of CCM but also has the significant advantage of being a more easily performed evaluation test for lower limb dysfunction than other assessment methods.

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