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Original Article

Changes in reaching skill in patients with cervical spondylosis after cervical decompression surgery

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Abstract. [Purpose] The aim of this study was to evaluate the changes in reaching function during a reaching task in cervical spondylosis (CS) patients before and after surgery. [Participants and Methods] Nine patients participated in the study. Wrist acceleration peaks were monitored pre- and postoperatively using a tri-axial accelerometer, and the Japanese Orthopedic Association (JOA) score was recorded preoperatively. Additional upper extremity function tests were performed pre- and postoperatively. Multiple stepwise regression analysis was used to investigate the contribution of wrist acceleration peak to the severity of clinical symptoms. Moreover, we compared the acceleration peaks produced during the reaching task before and after surgery. [Results] Multiple regression analysis showed that wrist acceleration peak, grip strength and pinch strength were associated with the upper extremity function of the JOA score, explaining 61.0% of the variance. There was a significant improvement in x-axis acceleration peak after surgery. [Conclusion] Our results suggested that quantitative assessments of reaching function are useful to objectively evaluate the changes in reaching function in patients undergoing cervical decompression surgery.

Key words: Cervical spondylosis, Reaching function, Wrist acceleration

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INTRODUCTION

Cervical spondylosis (CS) is a condition caused by spinal cord compression, unspecified degenerative changes, and segmental instability[1, 2)]. CS patients generally suffer from motor and sensory symptoms in the upper extremity, including numbness, stiffness and weakness[3–5)]. When conservative therapy fails, surgical treatment is applied to relieve compression of the spinal cord (i.e., cervical decompression surgery).

Several scales measuring the severity of physical disability have been developed to assess a patient's condition and the effectiveness of intervention. The Japanese Orthopedic Association (JOA) score is one of the most frequently-used outcome measures for evaluating functional status. The score consists of six domains: motor dysfunction in the upper extremities, motor dysfunction in the lower extremities, sensory function in the upper extremities, sensory function in the trunk, sensory function in the lower extremities, and bladder function. The minimum total score is 0 and the maximum is 17[6)]. Motor function of the upper extremities is mainly assessed based on evaluations of activities using the hand muscles, for example, eating

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with chopsticks or a spoon, and writing. The JOA score captures data related to the four extremity functions, and perceived disability[6–8]. Separately, the 10-second grip-and-release test (10-second test) is an effective test of hand function[9, 10]. In this test, the patient is asked to open and close their hands as quickly and fully as possible. Normal subjects are able to fully open and close their hands 20 times in 10 seconds.

Reaching function is affected in patients with CS. The dysfunction is caused by compression of the inter-neuronal system, including at C3–C4 level, which results in decreased corticomotoneuronal inputs to target reaching movements[11]. Evaluation of the reaching function is, therefore, also necessary for a comprehensive understanding of motor functions of the upper extremity. However, in contrast to numerous studies on the pathology of grasping and manipulation, the reaching function in patients with CS has not yet been adequately discussed. To the best of our knowledge, only Igarashi et al.[12] have compared reaching movement between CS patients and a control group, finding a variation in reaching movement in the patient group.

The aim of this study was to evaluate the reaching function in patients with CS using a tri-axial accelerometer. We observed kinematic changes while reaching, between before and after cervical decompression surgery. The contribution of wrist acceleration peak to the severity of upper extremity symptoms was also evaluated.

PARTICIPANTS AND METHODS

Nine male inpatients (mean age; 66.0 ± 7.3 years, height; 165.3 ± 4.5 cm, weight; 67.1 ± 7.2 kg, length of hospital stay; 25.8 ± 11.6 days) participated in the study. Only male patients were invited because they were recruited from our previous study participants[13]. In the previous experiment, we investigated the relationships between scapular retractor and shoulder rotator strengths, and the patients were asked to be naked to the waist for measuring the strengths of the scapular retractor. Female patients therefore were excluded because of privacy concerns. They were diagnosed as having cervical spondylotic myelopathy (5 patients), ossification of the posterior longitudinal ligament (3 patients), and cervical disk herniation (1 patient). The cervical segment was affected at C4–5 in one patient, C4–6 in four patients, C4–7 in three patients, and C5–7 in one patient. Individuals were referred if they had no visual disturbances or cognitive deficits. All patients received rehabilitation following surgery including stretching, muscle training of all four limbs, and targeted practice for activities in daily life. Informed consent according to the ethical standards of the Declaration of Helsinki was obtained from all patients after they received a thorough explanation of the purpose and procedures of the study. The study was approved by the Harunaso Hospital Research Ethics Committee (No.140105).

This was a prospective observational study. We measured the JOA scores pre-operatively, and kinematic variables during the reaching task and other clinical tests pre- (2.4 ± 1.7 days prior to operation) and postoperatively (18.1 ± 7.7 days after operation).

A tri-axial accelerometer (DL-111, S&ME Co., Tokyo, Japan) was used to record data during a simple reaching task. The axes were defined as follows: x-axis=frontal, y-axis=sagittal, z-axis=vertical. The accelerometer was connected to a portable data logger (DL3100, S&ME Co., Tokyo, Japan; sample frequency, 1 kHz; analog-to-digital conversion, 16 bit) to record acceleration data.

The reaching task was performed in accordance with Louis et al[14]. Each patient sat in front of a table. The accelerometer was attached, along with the recorder, to the measured wrist at the dorsal midpoint between ulnar and radial styloid processes, and secured with double-sided adhesive tape to minimize disruption during the movement. Reaching tasks were randomly measured for the dominant and the non-dominant upper extremities. In the initial position, the patient sat upright on the chair, and measurements commenced with the forearm resting on the table and the elbow at 90° flexion. The target was placed on the table at a distance of 30 cm in front of the hand. To simulate reaching in daily life, the target was a 0.5 kg cylindrical bottle (6.5 cm in diameter). Patients were instructed to reach for the target as accurately and quickly as possible. At the end of the movement, the measured forearm rested on the table in the initial position. The movements were repeated 10 times.

The severity of physical disability was assessed using the JOA score. Although the JOA score includes functions of the lower extremity and bladder, some studies have employed pertinent sub scores or upper extremity function measures (motor function of finger + sensory function) from the JOA score in isolation[15, 16]. Based on these studies, we selected the items related to upper extremity function: finger motor function (using chopsticks or a spoon, writing, and dressing), manual muscle testing of shoulder and elbow (the deltoid or biceps muscles), and upper extremity sensory function (touch and pain sensation and/or numbness), from the JOA score, and defined this grouping as JOA-UEF (6-point system) for the purpose of the present study.

Grip and pinch strengths and the 10-second test were also monitored. Dexterity was assessed by three subtests (numbers 8, 9 and 10) from the Simple Test for Evaluating Hand Function (STEF)[17]. These three subtests require patients to manipulate various small objects. For example, in subtest 10, patients reach and pinch a pin (0.3 cm in diameter and 4 cm long) and then bring the pin into a target space as quickly as possible, repeating this process six times. The time to complete each subtest was used for statistical analysis.

To determine which variable best predicted the severity of clinical symptoms, a multiple regression analysis (stepwise method) was performed with the pre-operative JOA-UEF as the dependent variable, and pre-operative kinematic variables (amplitudes of wrist acceleration peaks in three directions), grip strength, pinch strength, the 10-second test, and time of STEF as the explanatory variables. Goodness of fit was determined using adjusted R^2. The Wilcoxon signed-rank test was used to compare values pre- (2.4 ± 1.7 days prior to operation) and postoperatively (18.1 ± 7.7 days after operation). Statistical software SPSS ver. 23.0 J for Windows (SPSS Japan Inc., Tokyo, Japan) was used for the analyses, and $p<0.05$ was considered significant.

RESULTS

Multiple stepwise regression analysis indicated that the JOA-UEF could be predicted by the x-axis acceleration peak (β=0.41, p=0.03), grip strength (β= −0.63, p=0.02), and pinch strength (β=0.91, p<0.01). The adjusted R^2 value for fit of the model was calculated to be 0.61 (Table 1).

There were significant improvements in x-axis acceleration peak (p<0.05), the 10-second test (p<0.01), and STEF (p<0.05) after cervical decompression surgery (Table 2). The other axis peaks, grip strength, and pinch strength did not show significant changes after surgery.

DISCUSSION

We found that reaching function is associated with clinical upper extremity symptoms, and can be improved by surgery. Although a previous study reported that patients showed improved reaching trajectories after surgery[12)], this study provides the first assessment of reaching using an accelerometer in patients with CS.

Multiple regression analysis for the severity of upper extremity disability showed that the wrist acceleration peak significantly predicted the JOA-UEF score (Table 1). This acceleration peak has been used to assess reaching performance in patients with diseases of the central nervous system[18, 19)]. For example, the reaching acceleration peak was significantly lower in the paretic limb than in the non-paretic limb in stroke patients, and the acceleration difference between limbs was correlated with the upper extremity portion of the Fugl-Meyer Assessment[18)]. These studies suggested that lower acceleration implies prolonged recruitment of muscle activation during movement, producing more segmented and slower arm movement. In patients with CS, compression of the spinal cord leads to slower corticospinal tract conduction from the motor cortex to the upper extremity muscles[20)]. It is also thought that behavioral deficits in upper motor neuron syndrome are produced by prolonged recruitment of agonist contraction and delayed cessation of agonist contraction at the termination of movement[21)]. In our study, the wrist acceleration peak was related to the JOA-UEF, and thus to the severity of upper extremity disability. Therefore, the lack of muscle coordination may be one of the factors related to clinical symptoms in cervical spondylosis.

The 10-second test was a non-significant predictor of the JOA-UEF score (Table 1), although this test has been reported as a simple and reliable method of assessing coordination of the finger muscles[9, 22)]. This finding may be explained by the methodology of the 10-second test, which focuses only on finger flexion/extension, and is quite different from everyday actions performed with the upper extremity. The 10-second test is therefore not sufficient for the evaluation of complicated

Table 1. Results of multiple regression analysis for predicting JOA-UEF score

Dependent variable	Adjusted R^2	Explanatory variable	Standardized β	p value
JOA-UEF	0.61	X-axis acceleration peak	0.41	0.03
		Grip strength	−0.63	0.02
		Pinch strength	0.91	<0.01

JOA: Japanese Orthopedic Association; UEF: upper extremity function.

Table 2. Comparison of kinematic and upper extremity function values before and after surgery

		Pre-ope	Post-ope
JOA score	Total	11.7 ± 1.5	-
	JOA-UEF	3.4 ± 0.8	-
Acceleration peak (G)	X-axis	2.0 ± 1.3	2.7 ± 1.7*
	Y-axis	1.3 ± 0.7	1.5 ± 0.6
	Z-axis	1.4 ± 0.6	1.4 ± 0.6
Upper extremity function tests	Grip strength (kg)	32.5 ± 9.0	29.3 ± 9.7
	Pinch strength (kg)	6.2 ± 1.8	5.9 ± 1.6
	10-second test (number)	13.4 ± 4.4	17.2 ± 3.0**
	STEF (seconds)	38.6 ± 9.8	32.8 ± 5.7*

JOA: Japanese Orthopedic Association; UEF: upper extremity function; STEF: Simple Test for Evaluating Hand Function. *p<0.05; **p<0.01; Values are mean ± SD.

hand movements as required in the JOA-UEF, such as eating with chopsticks or a spoon, and writing.

The wrist acceleration peak significantly increased after cervical decompression surgery, suggesting that reaching function is improved after surgery (Table 2). In stroke survivors and Parkinson's disease patients, wrist accelerations increased after rehabilitation training[23)] and medication[19)], respectively. It was also reported that trajectories of reaching movements became smoother and more stable postoperatively[12)]. Our results are consistent with these previous studies. We think that this increased acceleration explains the recovery of muscle coordination by decompression of the spinal cord, including the corticospinal tract and inter-neuronal system. In the present study, only x-axis acceleration changed significantly after surgery, not y- and z-axis. This may be understood by considering the direction of the reaching task, which consisted of only forward-direction reaching. Levin[24)] reported that paresis hands had finger trajectories in the contralateral direction that were more varied, and more lacking in muscle coordination than in the forward direction. Future studies should consider to various directions of reaching task to evaluate reaching function and its recovery in more detail.

Although the strengths of gripping and pinching are significantly associated with JOA-UEF, these strengths did not show significant changes after surgery (Tables 1 and 2). The reason for this is unclear from the present study, but one underlying cause may be the length of time required for recovery. Prabhu et al.[25)] reported early postoperative improvements in tightness and sensory function in the upper limbs. In contrast, significant changes in upper extremity strengths were observed at six months after surgery[12)]. These results imply that early postoperative recovery may include coordination of the upper extremity, but not grip and pinch strengths. A future longitudinal study should be considered to monitor the recovery process of muscular strength.

Some limitations of the present study should be acknowledged. Firstly, we did not assess postoperative JOA scores. Although changes in JOA score after surgery have been widely acknowledged as a representative measure[26)], the post-operative JOA score was not monitored after discharge from the hospital. A future study monitoring post-JOA scores should be considered to clarify the longitudinal relationship between the JOA score and reaching skill. Secondly, we did not investigate magnetic resonance imaging results. Therefore, the relationships between damage to the inter-neuronal system and the wrist acceleration peak remain unclear. Lastly, this study was performed with a small number of patients, so the results should be interpreted with caution.

This study demonstrated that x-axis acceleration is related to clinical upper extremity symptoms, and can improve after surgery. This new knowledge may improve our understanding of clinical upper extremity symptoms in cervical spondylosis patients undergoing cervical decompression surgery. Therapies focused on the reaching function may improve patients' performance of activities in daily life.

Conflict of interest

None.

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