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Deficits of Movement Accuracy and Proprioceptive Sense in the Ipsi-lesional Upper Limb of Patients with Hemiparetic Stroke

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Abstract. [Purpose] Previous studies have reported on motor deficits in the ipsilateral upper limbs (UL) of a damaged brain hemisphere in motor tasks. However, little is known about sensory deficits on the ipsilateral side. Therefore, we investigated whether both motor and sensory function of the ipsilateral UL are affected in patients with stroke. [Subjects and Methods] Fifty patients with unilateral stroke and 40 age- and sex- matched normal subjects participated in this study. Subjects were evaluated on performance of a tracking task for motor function, and by the joint reposition test for integrity of proprioceptive sense in the ipsilateral UL. [Result] The comparison of the stroke group and the control group showed significant differences in performance of the tracking task and the joint reposition test. The accuracy index for the tracking task showed significant correlation with the error score for the joint reposition test in the stroke group. [Conclusion] These results suggest that the ipsilateral UL of stroke patients has impairment in sensory function which is related to proprioceptive sense, along with motor deficits. Therefore, we think that the difficulty stroke patients experience with motor tasks for the ipsilateral UL is induced by diminished integrity of sensorimotor function due to both sensory and motor deficits.

Key words: Visuomotor coordination, Proprioceptive sense, Motor deficits

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INTRODUCTION

Deficits of motor and sensory functions after stroke on the side contralateral to the damaged hemisphere are often evident[1)], whereas the ipsilateral side may be primarily regarded as normal or unaffected. However, there is increasing evidence of the presence of subtle motor deficits in motor performance on the ipsilateral side as well[2, 3)]. Ipsilateral motor deficits emerge during the acute phase and demonstrate chronic persistence[3–5)]; the reasons for ipsilateral motor deficits are still unclear. Clinical assessment tools may not be sufficient for differentiating ipsilateral motor deficits; however, deficits in dexterous motor and coordination function on the ipsilateral side have been identified in laboratory testing[2, 6–8)].

Earlier studies of ipsilateral motor deficits focused on motor weakness[9, 10)]. However, kinematic deficits in the ipsilateral upper limb in performance of various specific motor tasks requiring dexterity and coordination, such as a tracking task, a goal-direction movement, and a tapping task, have been found in recent studies[2, 6, 8, 11)]. On the basis of these observations, several possible mechanisms for ipsilateral motor deficits have been suggested, such as disrupted counterbalance of each hemisphere, dysfunction of the uncrossed corticospinal track, or the different roles of both sides in hemispheric functions[6, 7, 11–15)].

As mentioned above, patients with brain damage suffer from ipsilateral motor deficits in performance of the ipsilateral upper limb. Until now, most studies of ipsilateral deficits in stroke patients have concentrated on the motor, rather than sensory deficits. Little is known about sensory deficits on the ipsilateral side after stroke. Therefore, the purpose of the current study was to investigate the presence of motor and sensory deficits in the ipsilateral upper limb, and to examine the correlation between the two variables in patients with stroke using a tracking and reposition sense test.

SUBJECTS AND METHODS

Fifty hemiparetic stroke patients (25 patients with right brain injury and 25 patients with left brain injury) referred to a local rehabilitation hospital were consecutively recruited in the order of their registration. The inclusion criteria were; first ever stroke confirmed by medical history and brain MRI; right handed individual verified by the Edinburg Handedness Inventory; no symptoms of unilateral neglect or hemianopsia; no cognitive problem (Mini-Mental State Examination>24 points); no apraxic behavior (ideomotor apraxia score developed by Ambosoni et al. (>11 points)[16)];

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and no musculoskeletal dysfunction in the unaffected upper limb. We recruited 40 sex- and age-matched normal control subjects. To control the known effects of hand asymmetry, the accuracy and proprioceptive tests were performed by the 20 control subjects using their dominant right hand, and the remaining subjects used their non-dominant left hand. All subjects gave their written informed consent prior to participation, and this study was approved by the local ethics committee.

Tracking and joint position sense tests were conducted for the hand ipsilateral to the damaged hemisphere of the patients, and with the corresponding hand of the same side of the control subjects. All subjects were seated in front of a table, with the forearm comfortably supported and the elbow flexed at 90°. A plastic frame with an embedded potentiometer was used to measure the accuracy of movement and proprioceptive sense in the metacarpophalangeal (MP) joints. The potentiometer detected flexion/extension motion of the MP joint, and transmitted the analog signal to a computer with analog-to-digital data acquisition software, that sampled the signal at a frequency of 200 Hz.

In the tracking task, the subject was instructed to track the red target sine wave displayed for 15 seconds on the computer screen as accurately as possible. The response sine wave made by the subject was displayed as a black solid line, which tracked up as the MP joint was extended, and tracked down as the MP joint was flexed. The three trials were performed consecutively with 30s rest between trials. Accuracy of the motor performance was analyzed by an accuracy index (AI), which was normalized to the range of motion of the MP joint of each individual subject, and takes into account the differences between subjects in the excursion of the target and response waves[17].

$$AI = 100(P - E)/P$$

Where E is the root mean square (RMS) error between the target line and the response line, and P is the size of the subject's target pattern, calculated as the RMS difference between the sine wave and the midline dividing the upper and lower phases of the sine wave. The degree of P is determined by the scale of the vertical axis of the range of subject's MP joint motion.

Prior to the evaluation, three practice trials were provided after one demonstration, using sine waves which were different from the sine waves used in the actual test to prevent a learning effect. The joint position sense was evaluated on the MP joint ipsilateral to the damaged brain hemisphere of the patients, and the joint on the corresponding side of the control subjects. In addition, the same experimental apparatus and environment used for the performance of the tracking task were used. The subjects were instructed to actively reproduce the position of the MP joint which was passively positioned by the examiner. Three different passively-positioned angles were randomly presented, in terms of 50%, 70%, and 90% flexion of the total range of motion of the MP joint. The mean value of three trials of the joint reposition errors between the passively-positioned angles and the actively-positioned angles was calculated. The subjects wore a blindfold in order to eliminate visual feedback.

The χ^2 test was performed to analyze the differences in sex distribution between the patient and control groups. The independent t-test was performed to determine the significance of differences in age and accuracy of the tracking task/joint position sense. In addition, correlation between the AI and joint position sense was investigated using Pearson's correlation coefficient. PAWS 18.0 (SPSS Inc., Chicago, IL, USA) was used for the statistical analysis of all data, and statistical significance was accepted for p values < 0.05.

RESULTS

Demographic data for the stroke and control groups are shown in Table 1. No significant differences were observed between the two groups in terms of distribution of sex and age. The means±SD of the accuracy index and reposition error score of both groups are shown in Table 2. In terms of motor function, the stroke group showed a lower accuracy index in the MP joint than the control group. A higher score of reposition errors in the joint reposition test in relation to sensory function was observed in the stroke group, compared to the control group. The results of the statistical analysis indicate that both measures in the stroke group were significantly different from the control group ($p<0.05$). Ipsilateral sensory deficits showed significant correlation with motor deficits ($r= -0.549$) ($p<0.001$) (Table 2).

DISCUSSION

In the current study, we attempted to assess motor function using a tracking task for visuomotor coordination, and proprioceptive sense using a joint reposition test for the ipsilateral upper limb. Our findings reveal a lower accuracy index in the tracking task, and higher error scores in the

Table 1. Characteristics of each group

	Stroke Group	Control Group
Sample size	50	40
Age (y)	57.6±8.2	62.3±6.3
Gender (male/female)	25/25	22/18
Side of task performance (right/left)	25/25	20/20
Time post-stroke (mo)	22.6±12.5	

Table 2. Dependent variables in each group and correlation between dependent variables in the stroke group

	Stroke Group	Control Group	
Accuracy index	28.48±8.14	33.07±1.13	0.000*
Reposition error (°)	7.11±4.17	5.17±3.07	0.016*
	Correlation Coefficient		0.000*
	−0.549		

Mean ± SD

joint reposition test in the stroke group, compared to sex- and age-matched normal subjects. In addition, there was a negative correlation between the motor and sensory deficits, indicating stroke patients would have difficulty in performing complicated motor tasks requiring delicate sensoriomotor functions using pure integrity of movement accuracy and proprioceptive sense.

Our present results are in accordance with those of several previous studies[2, 8)], suggesting the presence of motor deficits in upper limbs ipsilateral to the damaged hemisphere in the visuomotor tracking task. A possible mechanism for the motor dysfunction in the ipsilateral hemisphere of stroke patients has been suggested by previous studies, which reported bilateral hemisphere activation when normal subjects executed a unilateral upper limb task[18–21)]. If functional integrity of both the right and left brain cortex is necessary for normal motor control of the upper limb, it is expected that the ipsilateral upper limb would be affected after stroke. In the present study, ipsilateral sensory deficits related to proprioceptive sense were also observed. According to our findings, ipsilateral sensory deficits may be connected with bilateral hemisphere activation during performance of motor tasks. The primary sensory cortex (S1) conveys efferent projection to the posterior parietal cortex (Brodmann's area 5 and 7), which is connected bilaterally through the corpus callsosum. In particular, the posterior parietal cortex integrates information related to proprioceptive input[22)]. Therefore, as suggested by our results, it is possible that disturbance of transcallosal transfer after unilateral brain damage may lead to ipsilateral sensory deficits. In addition, there is a close relationship between sensory and motor function, because the posterior parietal cortex is connected with the frontal motor areas. Thus, the posterior parietal cortex would have an effect on the initial movement and sensory feedback during performance of a complex motor task[22)]. On this basis, the correlation shown in our study between ipsilateral motor deficits and sensory deficits can be explained.

These findings imply that interest in the ipsilateral side of stroke patients should focus on ipsilateral sensory deficits as well as ipsilateral motor deficits. Motor deficits of the ipsilateral limbs of individuals with stroke have been reported in many studies; besides, our study showed sensory deficits related to proprioceptive sense. On the basis of these results, we think that the difficultly stroke patients experience in task performance using the ipsilateral upper limb may be affected by both motor and sensory deficits. Studies on recovery of motor deficits on the ipsilateral side after stroke are in progress. Jung et al.[14)] reported that motor deficits in the ipsilateral upper limb show maximal recovery within one month after onset of stroke, but the deficits do not completely recover. Thus, it will be necessary to study the recovery of ipsilateral sensory deficits after stroke onset, and we will be investigating this. We acknowledge that our study had some limitations, in that the effects of specific lesion location and the extent of the damage were not identified. Therefore, future studies will be required in order to determine more detailed mechanisms of other movement and sensory deficits, other than proprioceptive sense, in the ipsilateral upper limb of patients with unilateral brain injury.

REFERENCES

1) Kwakkel G, Kollen BJ, van der Grond J, et al.: Probability of regaining dexterity in the flaccid upper limb: impact of severity of paresis and time since onset in acute stroke. Stroke, 2003, 34: 2181–2186. [Medline] [CrossRef]
2) Kwon YH, Kim CS, Jang SH: Ipsi-lesional motor deficits in hemiparetic patients with stroke. NeuroRehabilitation, 2007, 22: 279–286. [Medline]
3) Yarosh CA, Hoffman DS, Strick PL: Deficits in movements of the wrist ipsilateral to a stroke in hemiparetic subjects. J Neurophysiol, 2004, 92: 3276–3285. [Medline] [CrossRef]
4) Sunderland A: Recovery of ipsilateral dexterity after stroke. Stroke, 2000, 31: 430–433. [Medline] [CrossRef]
5) Wetter S, Poole JL, Haaland KY: Functional implications of ipsilesional motor deficits after unilateral stroke. Arch Phys Med Rehabil, 2005, 86: 776–781. [Medline] [CrossRef]
6) Carey JR, Baxter TL, Di Fabio RP: Tracking control in the nonparetic hand of subjects with stroke. Arch Phys Med Rehabil, 1998, 79: 435–441. [Medline] [CrossRef]
7) Hermsdörfer J, Goldenberg G: Ipsilesional deficits during fast diadochokinetic hand movements following unilateral brain damage. Neuropsychologia, 2002, 40: 2100–2115. [Medline] [CrossRef]
8) Schaefer SY, Haaland KY, Sainburg RL: Ipsilesional motor deficits following stroke reflect hemispheric specializations for movement control. Brain, 2007, 130: 2146–2158.
9) Brodal A: Self-observations and neuro-anatomical considerations after a stroke. Brain, 1973, 96: 675–694.
10) Chollet F, DiPiero V, Wise RJ, et al.: The functional anatomy of motor recovery after stroke in humans: a study with positron emission tomography. Ann Neurol, 1991, 29: 63–71. [Medline] [CrossRef]
11) Debaere F, Van Assche D, Kiekens C, et al.: Coordination of upper and lower limb segments: deficits on the ipsilesional side after unilateral stroke. Experimental brain research. Experimentelle Hirnforschung. Experimentation cerebrale, 2001, 141: 519–529.
12) Colebatch JG, Gandevia SC: The distribution of muscular weakness in upper motor neuron lesions affecting the arm. Brain, 1989, 112: 749–763.
13) Hanna-Pladdy B, Mendoza JE, Apostolos GT, et al.: Lateralised motor control: hemispheric damage and the loss of deftness. J Neurol Neurosurg Psychiatry, 2002, 73: 574–577. [Medline] [CrossRef]
14) Jung HY, Yoon JS, Park BS: Recovery of proximal and distal arm weakness in the ipsilateral upper limb after stroke. NeuroRehabilitation, 2002, 17: 153–159. [Medline]
15) Laufer Y, Gattenio L, Parnas E, et al.: Time-related changes in motor performance of the upper extremity ipsilateral to the side of the lesion in stroke survivors. Neurorehabil Neural Repair, 2001, 15: 167–172. [Medline] [CrossRef]
16) Ambrosoni E, Della Sala S, Motto C, et al.: Gesture imitation with lower limbs following left hemisphere stroke. Archives of clinical neuropsychology: the official journal of the National Academy of Neuropsychologists, 2006, 21: 349–358.
17) Carey JR, Kimberley TJ, Lewis SM, et al.: Analysis of fMRI and finger tracking training in subjects with chronic stroke. Brain, 2002, 125: 773–788.
18) Blatow M, Nennig E, Durst A, et al.: fMRI reflects functional connectivity of human somatosensory cortex. Neuroimage, 2007, 37: 927–936. [Medline] [CrossRef]
19) Rao SM, Binder JR, Bandettini PA, et al.: Functional magnetic resonance imaging of complex human movements. Neurology, 1993, 43: 2311–2318. [Medline] [CrossRef]
20) Shibasaki H, Sadato N, Lyshkow H, et al.: Both primary motor cortex and supplementary motor area play an important role in complex finger movement. Brain, 1993, 116 (Pt 6): 1387–1398.
21) Winstein CJ, Grafton ST, Pohl PS: Motor task difficulty and brain activity: investigation of goal-directed reciprocal aiming using positron emission tomography. J Neurophysiol, 1997, 77: 1581–1594. [Medline]
22) Kandel ER, Schwartz JH, Jessel ITM: Principles of Neural Science. New York: Mc Graw Hill, 2000.