Dominant Limb Motor Impersistence Associated with Anterior Callosal Disconnection

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Abstract

Motor impersistence is known to occur more frequent after the right hemispheric lesion than the left. It is thus expected that, for a patient with a callosal lesion, motor impersistence may occur more frequently in the right (dominant) limb than the left. A 66-year-old right-handed man with an infarction involving the right medial frontal lobe and anterior corpus callosum developed motor impersistence in the right limb on bedside evaluation, which was also substantiated by an experiment using a finger dynamometer.

Keywords: callosal disconnection, motor intentional disorder, motor impersistence
Introduction

Callosal disconnection signs associated with cognitive functions predominantly represented in one hemisphere are manifested in the ipsilateral hand (e.g., agraphia in the left non-dominant hand and constructional apraxia in the right hand). Damage to premotor and prefrontal regions often results in motor-intentional disorders, in which initiation, maintenance, and termination of simple or complex movements are disrupted.\(^1,2\) Of these disruptions, motor impersistence (failure to maintain) is known to be more frequently observed after the right hemisphere lesion than the left.\(^3-5\)

It is thus expected that, for a patient with an isolated callosal lesion, motor impersistence may occur more frequently in the right (dominant) hand than the left. This hypothesis, however, has not yet been tested. We examined a patient with a callosal and right medial frontal lesion who showed motor impersistence in the right limb. We posit that this motor impersistence can be a sign of callosal disconnection, which prompted us to conduct an experiment.

Methods

Participants

Case description

A 66-year-old right-handed man was admitted due to weakness in the left limb. On an examination two days postonset, he rarely moved his left arm spontaneously but, on strong verbal requests, only a mild left hemiparesis (grade IV, greater in the leg than in the arm) was noted. Brain MRI showed an acute infarct involving the right medial frontal lobe and the corpus callosum (Fig 1-A, B).

On six days postonset, he marked all the targets in the Albert’s line cancellation task.\(^6\)
with both hands. Thirty trials (5 trials in 6 conditions) of bisection were conducted using either the left or right hand with lines located in the center (45 cm of viewing distance), left (25 cm left from the midline), and right hemispaces (25 cm right from the midline). Both the bisections by the left (-0.7 cm in the left, -5.9 cm in the center, -21.0 cm in the right) and right (-5.4 cm in the left, -17.0 cm in the center, -27.0 cm in the right) hands tended to err to the left when the lines were placed in the right hemispace.

On seven days postonset, tests for callosal disconnection showed ideomotor apraxia and agraphia in the left hand. He made accurate responses in 8/20 (40%) trials in the cross replication hand posture task and 34/80 trials (42.5%) in the finger tip cross localization task.

On eight days postonset, despite akinesia in the left limb, the maximum grip force of the left hand (225.4 N) (assessed by a hand dynamometer) was comparable to that of the right hand (245 N). On a request to raise both hands to the shoulder level in front and maintain for 20 sec, the left hand was slower to initiate but could steadily maintain the posture (“late but steady hand”), while the right hand was faster to move but did not maintain the posture (“fast but unsteady hand”) and showed frequent drops even to the neutral position despite verbal reminders. This right-sided motor impersistence was also observed in other tasks such as keeping both arms elevated to the shoulder side by side and keeping both legs elevated. However, no motor impersistence was noted in buccofacial muscles (e.g., sticking out the tongue for 20 sec). A 3-D diffusion tensor imaging taken 12 weeks postonset revealed an interruption of the white matter fibers in the genu and body of corpus callosum (Fig 1-C, D).

Control subjects

Six healthy male volunteers who were matched to the patient in age (mean age:
65.5 ± 2.8 years) without any history of neurological/psychiatric illnesses participated in the experiment. An informed consent was obtained from the patient and control subjects.

**Apparatus**

NK Pinch-Grip™ (NK Biotechnical Co., precision = 0.098 N, sampling rate = 32 Hz) was used to measure forces exerted by the index finger. This button-like finger dynamometer was located at two places on the table: 20 cm right or left from the midpoint (30 cm ahead from the midsternum). The workplace of the finger was covered with black cloth for the participant to better attend to the computer screen placed at a viewing distance of 70 cm.

**Experimental design**

The force control capabilities of the finger in force initiation and maintenance were examined. In the initiation task, the participant was instructed to press the Pinch-Grip with the index finger (1 cm above the dynamometer) in the shortest time possible once a white circle on the screen turned red and the reaction time was measured. Next, in the maintenance task, the participant was instructed to maintain 9.8 N on the dynamometer with the finger for 10 sec. while a circle on the screen turned white, green, and red if exerted force was 0.098 N below, within, and above 9.8 N, respectively, and the deviation from the designated force was measured.

A $2^2$ factorial design was applied to each force control task: hand ($H$) (right hand, RH; left hand, LH) and location ($L$) (right location, RL; left location, LL). The participant practiced each task four times, and then conducted the experimental conditions at random with the designated number of repetitions (six for the patient and two for the control group; the smaller number of repetitions for the control group was determined for their high
repeatability of performance identified at a preliminary experiment of our study).

**Results**

While the force control capabilities of the control group were relatively stable (around 258 ms in initiation time and -0.06 N in maintenance error), those of the patient were much worse and varied largely depending on $H$ and $L$ (Figure 2). The ratios of the overall performance averages (SDs) of the patient to those of the control group were 4.6 (4.2) in initiation and 16.7 (9.7) in maintenance.

*Force initiation (Fig 2A):* ANOVA showed $H$ ($F(1, 18) = 16.22, p = 0.001$) and $H \times L$ ($F(1, 18) = 4.70, p = 0.044$) significant in the patient. Specifically, LH (1438 ms) was slower than RH (897 ms), and LH was much slower at RL (1634 ms) than LL (1200 ms) ($F(1, 18) = 5.8, p = 0.028$) whereas RH was not significantly different between RL (844 ms) and LL (963 ms) ($F(1, 18) = 0.4, p = 0.52$).

*Force maintenance (Fig 2B, Fig 3):* ANOVA found $H$ ($F(1, 20) = 120.21, p < 0.001$), $L$ ($F(1, 20) = 8.67, p = 0.008$), and $H \times L$ ($F(1, 20) = 5.19, p = 0.034$) significant in the patient. RH (-2.27 N) produced a significantly larger error than LH (-0.27 N) (Fig. 3) and RH was worse at RL (-2.74 N) than LL (-1.79 N) ($F(1, 20) = 5.19, p = 0.03$) whereas LH was not significantly different between RL (-0.32 N) and LL (-0.21 N) ($F(1, 20) = 2.19, p = 0.53$).

**Discussion**

Left limb hypokinesia observed clinically and experimentally in our patient can be associated with a right medial frontal lobe lesion. The most interesting behavior in our patient,
however, was motor impersistence in the right hand. This deficit cannot be attributed to a motor or sensory defect since the right hand power/coordination and sensation were flawless and MRI showed no abnormal lesion in the left hemisphere, brain stem, and cerebellum. The dominant limb motor impersistence observed by eye inspection on bedside evaluation corroborated the result of the force maintenance experiment. The force maintenance ability of the patient’s right hand was 8.5 times lower than that of the patient’s left hand and 21.5 times lower than that of the controls. However, the fluctuation of force production (Fig. 3) in the patient (representing motor impersistence) needs to be differentiated from action tremor. The fluctuation in our patient was irregular with a frequency of < 1 Hz and the force level intermittently dropped to almost zero, which is different from the feature of action tremor—regular, repetitive and fast fluctuation. Thus, our study is first to demonstrate that motor impersistence observed at a gross level can be quantified at a “micro” level using a finger dynamometer. Although our patient’s left hand was much superior to the right hand in the force maintenance ability, its performance was quite below the normal range of controls. This may represent subtle motor weakness associated with a right medial frontal lesion or partial injury of the right hemisphere motor intention system that mediates force maintenance.

In the force initiation experiment, there was a hemispace effect: placing the left hand into the right hemispace worsened the akinesia. In the force maintenance experiment, there was also a space effect: placing the right limb in the right hemispace worsened motor impersistence. As often observed in patients with frontal lesions, our patient had ipsilesional neglect associated with right frontal lesion. Thus, the space effect of akinesia and motor impersistence can be explained as an aggravation of motor intentional disorders when the hand is placed in the neglected (right) hemispace.
References


Figure 1. Neuroimaging findings of the patient. The diffusion weighted (A) and T2 weighted (B) MRIs show an acute infarct in the right anterior cerebral artery distribution involving the right medial frontal lobe and corpus callosum. The fiber tractography of the entire corpus callosum from 3-D diffusion tensor imaging (C and D) reveals an interruption of the white matter fibers in the genu and body of the corpus callosum. The tracks were terminated if fraction anisotropy in the voxel decreased below 0.3 or if the angle between adjacent voxels along a track was greater than 85 degrees. The 3-D diffusion tensor imaging taken 12 weeks postonset showed that an interruption of the white matter fibers in the genu and whole body of the corpus callosum might be correlated with the patient's disconnection syndrome.
Figure 2. (A) Force initiation time, (B) Error in force maintenance.

Force control capabilities of the patient and control group (RH = right hand, LH = left hand, RL = right location, LL = left location). (A) In force initiation, the patient was much slower than the control group and showed longer times with LH and especially at RL with LH. (B) In force maintenance, the patient was slightly inferior to the control group with LH but was much more impersistent with the non-paretic RH than the control group and showed significantly much larger errors at RL with RH.
Figure 3. (A) A force maintenance trial in the patient, (B) A force maintenance trial in the control group. An illustration of force maintenance trials in the patient and control group. (A) The patient showed a much larger error with the right hand. (B) The control showed an insignificant difference between the right and left hand.