Motor intentional disorders in right hemisphere stroke

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Abstract

Objective: Damage to premotor and prefrontal regions results in motor intentional disorders (MIDs) that disrupt initiation, maintenance, and termination of volitional movements. MIDs occur more frequently after right than left hemisphere injury. The aim of this study was to evaluate the prevalence of MIDs in patients with right hemisphere stroke and the factors that have influence on MIDs.

Methods: Subjects consisted of 25 consecutive patients with right hemisphere stroke and 12 normal controls. They underwent a series of experiments using force dynamometer along with bedside examination.

Results: It was identified that the force control test screened for MIDs with a higher sensitivity than bedside exams: motor akinesia (38% vs. 11%), motor impersistence (50% vs. 10%), and motor perseveration (47% vs. 25%). The patients were significantly inferior to the controls in terms of force control capabilities in the four force control phases (1.6-17.0 times). The location and area of lesion and space of force production were not related to the severity of MIDs whereas the presence of neglect was related to the severity of MIDs.

Conclusions: Our results suggest force dynamometer is a sensitive method to detect MIDs and the presence of neglect may influence the frequency of MIDs.

Key Words: Motor intentional disorders, force dynamometer, right hemisphere stroke, neglect
INTRODUCTION

Occipital and temporoparietal association cortices mediate the perception and recognition of various sensory stimuli, whereas the premotor and prefrontal regions are involved in action-intention of simple or complex movements. When this action-intention system is damaged, various motor-intentional disorders (MIDs) occur.

MIDs can be classified according to three basic components of movement: initiation, maintenance, and termination. A purposeful movement is first initiated, then maintained for a certain period of time, and finally terminated. A complex movement may constitute a combination of these basic components with various temporal and spatial codes. Failures to initiate, maintain, or terminate a movement are termed as motor akinesia, motor impersistence, and motor preservation, respectively.

Lesion localization of MIDs has not been studied systematically. Some studies have shown that MIDs are most frequently associated with bilateral hemispheric lesions. However, when lesions are unilateral they are located more in the right hemisphere. Furthermore, most of the previous MID studies involving patients with right hemisphere injuries were based on clinical observations rather than objective measurements.

In testing MIDs, clinicians rely on behavioral observation during examination or bedside tests. In a test for motor akinesia, the patient is asked to lift the arm ipsilateral to the lesion while the hand is touched; however, the absence of arm movement may result from sensory-perceptual failure (inattention) or motor-intentional failure (akinesia). To differentiate these two failures, a crossed response task is used in which the patient is asked to raise the right arm while the left hand is touched and vice versa. Next, to test motor impersistence, the patient is asked to maintain a posture such as protruding the tongue, keeping the eyes closed, or keeping the arms extended for 15 to 20 seconds. Finally, to test motor perseveration, the patient is asked to draw the Luria loop, a simple or complex figure,
or cancel lines.\textsuperscript{1}

Although these observational tests are beneficial to identify the presence of an MID at the bedside, they can neither quantify the severity of an MID nor detect subtle MIDs. The severity of an MID has been quantified by measuring the reaction time of a movement in the right or left hemispace (spatial akinesia or hypokinesia)\textsuperscript{7} or in a leftward or rightward movement (directional akinesia or hypokinesia).\textsuperscript{8} To our knowledge few studies have been conducted to quantify motor impersistence and perseveration in patients with right hemispheric strokes.

Another limitation of previous studies is that the force component of movements has not been considered in analysis. As far as the action-movements of limbs are concerned, besides the three basic movement components (times of initiation, maintenance, and termination), there are other variables to be considered: space (the peripersonal space where the action occurs), direction of movement, and force control. Even though motor intentional movements involve force control capabilities in the context of time, space, and direction of movement, previous studies have focused only on the time and space of movement. In a case study by Seo et al.,\textsuperscript{9} the patient with callosal infarction showed a distinct fluctuation in force control when he was asked to maintain a designated force on a finger dynamometer with the index finger of the right hand, which indicates a novel callosal disconnection sign that cannot be detected by bedside evaluation.\textsuperscript{9} This case study demonstrates that the quantification of force control capability can be effectively applied to the understanding MID characteristics.

In this study we tried to quantify the severity of MIDs (akinesia, impersistence, and perseveration) in terms of the force control capability in patients with right hemispheric injuries using a finger dynamometer. The specific aims of our study were to (1) compare the frequency of MID screened by conventional bedside exams with the corresponding results from the force control capability test proposed in the study and (2) to examine whether or not
the presence of neglect, hemispatial effect, and location of lesions affect the severity of MID.

**MATERIALS AND METHODS**

**Participants**

*Patients*

Right-handed patients \((n = 25)\) who were admitted to the Neurology Department at Samsung Medical Center in Seoul, Republic of Korea due to a right hemispheric stroke participated in the present study. The patients consisted of 21 men and 4 women with a mean age of 63.8 years \((SD = 10.9, \text{ range } = 44 \text{ to } 80)\). The right hemisphere strokes were demonstrated by CT \(3\) or MRI \(22\) performed during hospitalization. Among the patients, 24 had cerebral infarctions and 1 had an intracerebral hemorrhage. None of the patients had lesions in the left hemisphere except for minor lacunae and deformities and arthritis in the fingers. All patients were examined within three months after the onset with a mean time of 46.0 days \((SD = 19.2, \text{ range } = 4 \text{ to } 68)\).

*Controls*

Twelve individuals \((10 \text{ men and } 2 \text{ women})\) with a mean age of 65.5 years \((SD = 3.9, \text{ range } = 61 \text{ to } 71)\) with no history of neurologic or psychiatric illnesses served as controls. All the controls were right-handed, which was confirmed by the Edinburgh Handedness Inventory.\(^{10}\)

**Bedside examination for motor intentional disorders**

No patient demonstrated hemiparesis or sensory abnormalities in the right arm. To test motor akinesia the patients were asked to lift the arm while the hand was touched and then conduct the crossed response task. Motor akinesia in the right arm was diagnosed if in more than 5 out of 20 trials the patient showed no response in the right arm to the left-sided stimulus for 5 seconds while making a correct response with the left arm to the right-sided
stimulus. Next, to test motor impersistence, the patients were asked to keep their right arms extended for 20 seconds and then close their eyes for 20 seconds. Motor impersistence was diagnosed if the patient failed any of the maintenance tasks. Finally, to test motor perseveration the Luria loop test was administered. The patients were asked to draw three times the Luria figure having three loops. Motor perseveration was diagnosed if the patient drew more loops in at least two trials.

**Assessment for hemispatial neglect**

One of the common behavioral abnormalities associated with right hemisphere injury is hemispatial neglect. To assess hemispatial neglect, a test battery consisting of three line-bisection tasks, two cancellation tasks, and one figure copying task was administered. The line types selected in the study, which were from the Character Line Bisection Task, were solid, letter, and star lines. The cancellation tasks included a modified version of Albert's line cancellation test and a star cancellation task. The figure copying task was scored by a combined score in the two copying tests: the modified Ogden Scene test and the Two Daisy figure. All tests employed in the study have been found reliable and valid. Contralesional neglect was defined according to the total neglect score. We defined the criteria for hemispatial neglect as a total score that exceeded the mean plus 2SD of 81 normal control subjects’ performances.

**Lesion analysis**

The lesions identified by axial CT or MRI scans were traced on the best fitting template provided by Damasio and Damasio. A neurologist who was blind to the patients’ clinical information coded the lesion locations as anterior, posterior, or both with reference to the central sulcus. The lesion’s boundary on CT or T2-weighted MR images was outlined using a manual pixel-wise method with the aid of a PACS workstation (General Electric, Ohio). The volume of each lesion was computed by multiplying the lesion area in CT or MRI
slices by the thickness of the slice plus the interslice gap distance. A single neurologist who was blind to the clinical statuses of the patients performed the lesion volume measurement.

A neurologist who was blinded to the patients’ clinical information also manually traced lesions on diffusion-weighted MRI or CT on the standard T1-weighted MRI templates provided by MRIcro (http://www.mricro.com). The standard templates used for our study were 12 axial slices (-32, -24, -16, -8, 0, 8, 16, 24, 32, 40, 50, 60 on Talairach z coordinate). Then, he overlapped lesion of patients with MIDs and those without MIDs respectively. The number of overlapping lesions was coded with increasing frequencies from violet (n=1) to red (n=maximum number in the respective group).

**Experimental apparatus**

The NK Pinch-Grip™ (precision = 0.098 N, sampling rate = 32 Hz; NK Biotechnical Co.) was used to measure the force control capabilities of the index finger. The finger dynamometer was located 30 cm in front and 20 cm to the right or left of the midsternum and a computer screen was located 70 cm from the eye (Figure 1). To better direct the participant’s attention to the screen, the work area of the index finger was covered with a black cloth.

**Experimental procedure**

The force control capabilities of the index finger in the four phases of initiation, development, maintenance, and termination (Figure 2) were evaluated as follows:

**Force initiation:** To quantify the extent of motor hypokinesia, the time to initiate force development was measured. Positioning the index finger 1 cm above the finger dynamometer, the participant was instructed to press the finger dynamometer as fast as possible once a signal was presented. The signal was a white circle (Figure 3A) on the screen turning red and the time to signal randomly varied from 2 to 5 sec.

**Force development:** The force development phase was added to the three basic components
of movement (initiation, maintenance, and termination) because force should be increased to a designated level before force maintenance. The participant was instructed to increase force on the finger dynamometer with the index finger to 9.8 N in the shortest time possible and the time to reach the target force was measured. Visual feedback was provided on the screen as illustrated in Figure 3B: a white ball moved up in proportion to force produced and turned green as it reached the target force (indicated by a red line). The target force level was selected from 4.9, 9.8, and 19.6 N by considering the discriminability of force control capability between the patient and control groups and the force development capability of the patient group identified in the preliminary test.

**Force maintenance**: To quantify the extent of motor impersistence, the error of force maintenance from a target force was measured; a positive value of force maintenance error indicated an overexerted force. The participant was instructed to keep pressing the finger dynamometer at 9.8 N with the index finger for 10 sec. A circle (Figure 3B) on the screen turned white, green, then red as the exerted force was 10% below, within, and above the target force, respectively.

**Force termination**: To quantify the extent of motor perseveration, the time to terminate force production was measured. The participant was instructed to release his or her index finger from the finger dynamometer in the shortest time possible once a signal was presented.

The force control test was repeated six times for the patient group and twice for the control group at the right and left locations (RL and LL). The smaller number of repetitions for the control group was determined for its relatively high repeatability (SD between trials for initiation, development, maintenance, and termination tasks: 121 ms, 34 ms, 0.2 N, and 123 ms) of measurement identified at a preliminary experiment in the study. Prior to the experiment four practice trials were administered and additional exercise was allowed as necessary. The Institutional Review Board at the medical center approved the study protocol.
and all of the participants provided written informed consent prior to participation.

**Criteria for MIDs in force control performance**

The prevalence of MIDs among patients was identified by referring to the 99% confidence intervals of the force control capabilities of the normal participants. Patients whose performance was worse than the reference limits of the force control capabilities were screened as those with MIDs.

**Statistical data processing**

The present study excluded observations beyond the corresponding 95% confidence intervals as outliers among repeated observations (Barnett and Lewis, 1994) and excluded single observation cases. For the patient and control groups, 49 (17% of measurements) and 10 (4%) outliers were excluded from analysis, respectively. ANOVA was conducted using SAS v. 6.0 and a 0.05 significance level was applied in statistical testing.

**RESULTS**

**Prevalence rates of MIDs according to the bedside exam and force control test**

It was identified that the proposed force control test screened for MIDs with a higher sensitivity than bedside exams. The prevalence rates of MIDs identified by the bedside exam were 11% (2/18) for motor akinesia, 10% (2/20) for limb motor impersistence, and 25% (5/20) for motor perseveration. On the other hand, the prevalence rates of MIDs identified by the force control test were higher at 38% (8/21) for motor akinesia (initiation), 85% (17/21) for development, 50% (10/20) for motor limb impersistence (maintenance), and 47% (7/16) for motor perseveration (termination).

**MIDs in finger dynamometer experiments in patients versus normal controls**

The patients were significantly inferior to the controls in terms of force control capabilities in the four force control phases. Table 1 shows that the force control capabilities
of the patients were significantly lower (1.6 ~ 16.3 times at $\alpha = 0.05$) than those of the controls, and more severe deterioration was observed in the development (4.8 times) and maintenance (16.3 times) phases.

**Factors affecting MIDs**

*Effect of hemispatial neglect:* The force control capabilities of patients with spatial neglect were significantly lower than those of patients without spatial neglect in all four phases (Table 2). The average force control capabilities of the patients with spatial neglect were 561 ms (SD = 211) in initiation, 266 ms (SD = 129) in development, -1.09 N (SD = 1.39) in maintenance, and 629 ms (SD = 227) in termination. Meanwhile, the capabilities of the patients without spatial neglect showed 287 ms (SD = 102 ms) in initiation, 220 ms (SD = 159) in development, -0.26 N (SD = 0.50) in maintenance, and 478 ms (SD = 164) in development.

*Space effect:* The effect of space on the patients with regard to force control capability was not significant in any of the four phases of force production (Table 2). The differences in force control capabilities between the left and right positions were -5 ms in initiation, 10 ms in development, 0.01 N in maintenance, and -29 ms in termination.

*Lesion location effect:* The effect of lesion location (A: anterior; P: posterior; AP: anterior and posterior) on force control capability was not significant in any of the four phases. In the force initiation and development phases the capabilities of the AP group (initiation time = 629 ms; development time = 485 ms) were relatively decreased compared to those of the A (initiation time = 495 ms, development time = 264 ms) and P (initiation time = 330 ms, development time = 244 ms) groups. On the other hand, in the maintenance phase the capabilities of the A (maintenance error = -1.02N) and P (maintenance error = -0.97 N) groups were slightly lower than that of the AP group (maintenance error = -0.73N). Lastly, in the termination phase, the P group (termination time = 783ms) showed a relatively lower
capability than the A (termination time = 541ms) and AP (termination time = 553ms) groups. However, these lesion location effects were not statistically significant in any of the four phases at $\alpha = 0.05$ (Table 2).

As presented in Figure 4, we also compared the lesions of patients with and without MIDs in each aspect of motor intention tasks. Chi-square tests revealed that there were no significant differences between the two groups in all phases.

**DISCUSSION**

Previous studies have reported that stroke patients show decreased dexterity in the unaffected (ipsilesional) hand compared to healthy controls. Desrosers et al.\textsuperscript{17} reported that manual dexterity of the unaffected hand was worse in stroke patients, although grip strength and cortical sensation (two-point discrimination or touch/pressure threshold) did not significantly differ. Subsequently, Sunderland et al.\textsuperscript{18} replicated these findings and concluded that impaired dexterity of the ipsilesional hand is not always correlated with the loss of grip strength in the contralesional hand and that cognitive deficits rather than primary sensorimotor losses contribute to the impaired dexterity. Although we did not assess grip strength and manual dexterity, the abnormal performances of the patients in motor intentional tasks could not be attributed to elementary sensory or motor deficits for the following reasons: First, on neurological examinations, our patients showed normal hand grip strength and sensory functions. Second, our motor intentional tasks, which require pressing or releasing a button-like dynamometer, were simple enough that manual dexterity would not be a significant factor. Third, the performances of the patients varied according to the force production phase and were affected by the presence of neglect, which cannot be explained by sensorimotor factors (discussed in detail later).

The present study compared the prevalence rates of MIDs by the conventional
bedside methods with those of MIDs by our experimental tasks using a finger dynamometer. The MID prevalence rates by the conventional method ranged from 10 to 24% whereas those by our proposed method ranged from 48 to 85%, indicating that the finger dynamometer method was more sensitive in the detection of MIDs.

Of the four force control tasks in our study, force development and force maintenance seemed to be the most sensitive. This study employed a force control test because we considered force control to be an essential component of motor intention. The magnitudes of a decrease in mean performance compared to healthy controls were much larger in force development (4.8 times) and force maintenance (16.3 times) than in force initiation (1.7 times) and force termination (1.6 times). The underlying reason for these performance differences, which depend on the force control phase, remains unclear; however, of the four tasks, the force initiation and termination tasks require mainly time control, whereas force development and maintenance require both time control and control of the magnitude of force production, which may make the latter two tasks more sensitive.

Our results demonstrated that deficits in force initiation, maintenance, and termination were associated with the presence of neglect. The patients with neglect showed more severe motor intentional deficits than those without neglect. Many studies have suggested that intentional deficits as well as attentional deficits induce unilateral spatial neglect.\textsuperscript{19-21} Subsequent studies have also shown that most patients with spatial neglect have both intentional and attentional biases, implying that networks subserving attention and intention are closely associated to and influence one another.\textsuperscript{22} Thus, it is possible that motor-intentional deficits in our patients aggravated the neglect. Our motor intention tasks required subjects to interact with the stimulus on the screen. Therefore, it is also possible that attentional deficits in our patients with neglect might have contributed to decreased performances, even though we purposely presented the stimulus around the midline of the
screen, given that patients with neglect are usually not responsive to stimulus off the midline toward the contralesional space.

Contrary to our expectations, however, no significant effect of space on force control capability was found in patients with MIDs. It has been suggested that there are two kinds of motor akinesia or hypokinesia that contribute to spatial neglect\textsuperscript{21,23}: failure to move in the contralesional space regardless of the direction of action (spatial akinesia or hypokinesia) and failure to move toward the contralesional space regardless of the space of action (directional akinesia or hypokinesia). Likewise, we expected that not only akinesia but also motor impersistence and perseveration would occur more frequently on the contralesional space (spatial MIDs). Of the spatial versus directional akinesia, directional akinesia has been replicated in many studies\textsuperscript{7,8,21,24} whereas spatial akinesia has been reported only in case studies.\textsuperscript{23} Although we did not test the directional effect of akinesia, results of previous studies together with our study suggest that spatial akinesia may not be as robust as directional akinesia.

Lastly, it was hypothesized that anterior lesions would be more associated with MIDs than posterior lesions. Motor akinesia has been known to be related with lesions in the right medial frontal region\textsuperscript{25} and motor impersistence primarily occurs after right dorsolateral lesions.\textsuperscript{4} Anterior lesions are more likely to be associated with motor perseveration than lesions restricted to posterior areas.\textsuperscript{22} However, we failed to find anatomical differences between patients with and without MIDs. One explanation for not being able to replicate the association between MIDs and anterior lesions may be that most of our patients had both anterior and posterior lesions and the number of patients having isolated anterior or posterior lesions was not large enough to achieve statistical power. Alternatively, a previous study showed that the human inferior parietal lobule might subserve not only perceptual functions, but also the motor role of neglect.\textsuperscript{8} A recent diffusion tensor imaging study reported that there
were profound connections between frontal and parietal regions, which may provide insight into the interpretation of our results.
Table 1. Comparison of motor performances between normal controls and patients.

<table>
<thead>
<tr>
<th>Motor phases</th>
<th>Normal controls</th>
<th>Patients</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation (ms)</td>
<td>300.6 (120.7)</td>
<td>542.6 (283.5)</td>
<td>( t (150) = -9.52, p &lt; 0.001 )</td>
</tr>
<tr>
<td>Development (ms)</td>
<td>75.5 (33.8)</td>
<td>360.1 (440.7)</td>
<td>( t (147) = -7.73, p &lt; 0.001 )</td>
</tr>
<tr>
<td>Maintenance (N)</td>
<td>0.054 (0.172)</td>
<td>-0.893 (1.336)</td>
<td>( t (146) = 8.52, p &lt; 0.001 )</td>
</tr>
<tr>
<td>Termination (ms)</td>
<td>355.2 (123.1)</td>
<td>561.9 (233.8)</td>
<td>( t (179) = -7.97, p &lt; 0.001 )</td>
</tr>
</tbody>
</table>
Table 2. Effect of four motor control factors on motor intentional deficits.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Initiation (ms)</th>
<th>Development (ms)</th>
<th>Maintenance (N)</th>
<th>Termination (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ms)</td>
<td>(ms)</td>
<td>(N)</td>
<td>(ms)</td>
</tr>
<tr>
<td>Neglect (+) (N=17)</td>
<td>561 (211)</td>
<td>266 (129)</td>
<td>-1.090 (1.386)</td>
<td>629 (227)</td>
</tr>
<tr>
<td>Neglect (-) (N=8)</td>
<td>287 (102)</td>
<td>220 (159)</td>
<td>-0.259 (0.502)</td>
<td>478 (164)</td>
</tr>
<tr>
<td>P value</td>
<td>t (109) = -9.48, p &lt; 0.01</td>
<td>t (64) = -1.45, p = 0.15</td>
<td>t (84) = 4.27, p &lt; 0.01</td>
<td>t (65) = -3.31, p &lt; 0.02</td>
</tr>
<tr>
<td>Right space</td>
<td>546(280)</td>
<td>356(418)</td>
<td>-0.28(1.254)</td>
<td>577(254)</td>
</tr>
<tr>
<td>Left space</td>
<td>539(289)</td>
<td>366(465)</td>
<td>-0.834(1.274)</td>
<td>548(214)</td>
</tr>
<tr>
<td>P value</td>
<td>F(1,18) = 0.8, p = 0.38</td>
<td>F(1,17) = 0.71, p = 0.41</td>
<td>F(1,17) = 0.02, p = 0.68</td>
<td>F(1,13) = 1.84, p = 0.20</td>
</tr>
<tr>
<td>Anterior lesion (A) (N=9)</td>
<td>495 (205)</td>
<td>264 (149)</td>
<td>-1.015 (1.380)</td>
<td>541 (223)</td>
</tr>
<tr>
<td>Posterior lesion (P) (N=3)</td>
<td>330 (173)</td>
<td>244 (144)</td>
<td>-0.971 (0.308)</td>
<td>783 (148)</td>
</tr>
<tr>
<td>Anterior &amp; posterior (AP) (N=13)</td>
<td>629 (314)</td>
<td>485 (618)</td>
<td>-0.726 (1.289)</td>
<td>553 (240)</td>
</tr>
<tr>
<td>P value</td>
<td>F(2,18) = 0.9, p = 0.42</td>
<td>F(2,17) = 1.03, p = 0.38</td>
<td>F(2,17) = 0.39, p = 0.68</td>
<td>F(2,13) = 0.66, p = 0.53</td>
</tr>
</tbody>
</table>
Figure 1. The layout of finger press workstation. The finger dynamometer was placed on an imaginary line 30 cm from the subject’s midsternum and 20 cm to the right or left of midsagittal plane of the subject. The viewing distance of the computer screen was 70 cm.
Figure 2. Four phases of the force control capabilities of the index finger: force initiation, development, maintenance, and termination.
Figure 3. Computer screens presented during force production phases. In the initiation and termination phases, a white circle on the screen turned red, which signaled the subject to start (initiation) or stop (termination) to press the button. The time from the white to the red circle varied from 2 to 5 sec (A). In the development and maintenance phases, a visual feedback was provided on the screen: a white ball moved up in proportion to force produced and turned green as it reached the target force (indicated by a red line) (B).
Figure 4. Comparison of lesions in patients with and without MIDs in initiation (A), maintenance (B) and termination (C) phase. Note that there were no significant differences in lesion location and extent between the two groups in all phases.
References


