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Research paper

# Functional lateralization in cingulate cortex predicts motor recovery after basal ganglia stroke

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## HIGHLIGHTS

- A longitudinal study on basal ganglia (BG) stroke patients is performed.
- FMRI data were collected across three motor recovery stages.
- Close interactions between BG and cerebellum during motor recovery were revealed.
- Ipsilesional attention modulation in the early stage after BG stroke was revealed.
- Contralateral cingulate cortex activation was associated with an improved recovery.

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## ABSTRACT

The basal ganglia (BG) is involved in higher order motor control such as movement planning and execution of complex motor synergies. Neuroimaging study on stroke patients specifically with BG lesions would help to clarify the consequence of BG damage on motor control. In this paper, we performed a longitudinal study in the stroke patients with lesions in BG regions across three motor recovery stages, i.e., less than 2week (Session 1), 1–3 m (Session 2) and more than 3 m (Session 3). The patients showed an activation shift from bilateral hemispheres during early sessions (<3 m) to the ipsilesional cortex in late session (>3m), suggesting a compensation effect from the contralesional hemisphere during motor recovery. We found that the lateralization of cerebellum(CB) for affected hand task correlated with patients' concurrent Fugl-Meyer index (FMI) in Session 2. Moreover, the cingulate cortex lateralization index in Session 2 was shown to significantly correlate with subsequent FMI change between Session 3 and Session 2, which serves as a prognostic marker for motor recovery. Our findings consolidated the close interactions between BG and CB during the motor recovery after stroke. The dominance of activation in contralateral cingulate cortex was associated with a better motor recovery, suggesting the important role of ipsilesional attention modulation in the early stage after BG stroke.



## 1. Introduction

Basal ganglia (BG) is involved in higher order motor control such as movement planning and execution of complex motor synergies [1]. It has been proposed that dynamic interactions among multiple neural networks composed of frontoparietal cortices, the BG and CB regions played an important role in motor skills acquisition [2]. Animal studies have demonstrated that lesions in BG have direct influence on grip force behavior [3]. An altered balance of facilitatory and inhibitory influence on the function of frontal cortex was conceived as effects of basal ganglia dysfunction [4]. Dubrowski et al. reported a single chronic stroke patient with a failure to integrate sensory information in motor programming after a unilateral BG damage [5]. However, functional neuroimaging studies are rare on patients with BG stroke, which would reveal the isolated effects of BG damage on motor control. Besides, the brain plasticity during

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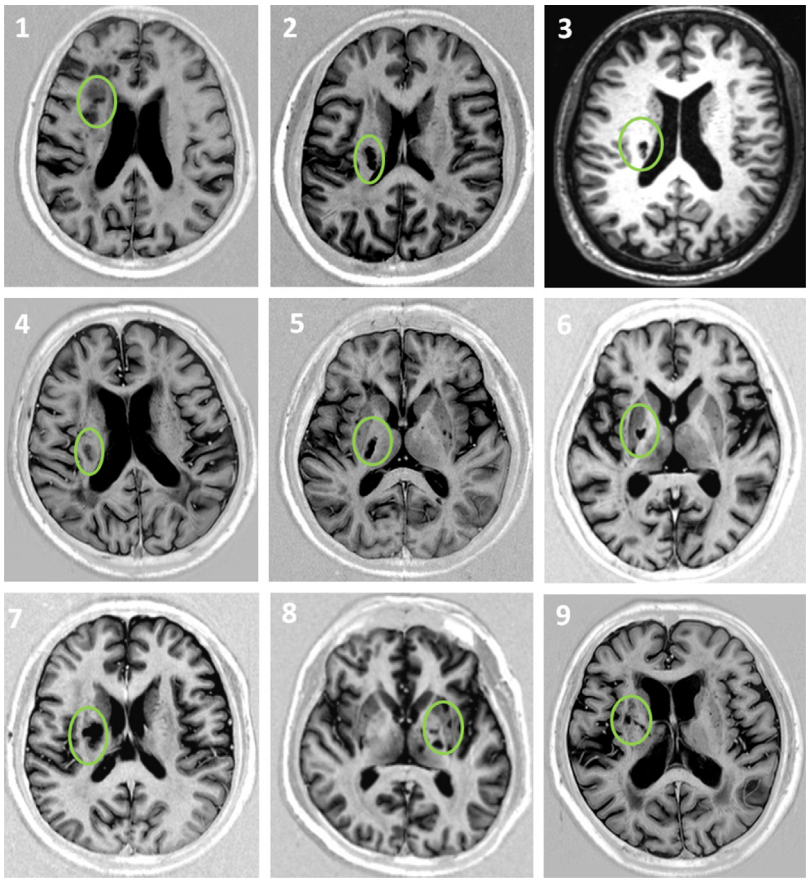


**Fig. 1.** Axial T1-weighted image for each patient, in which the infarct area was circled by an experienced radiologist. The numbers correspond with the patient ID in Table 1. Image 3 was obtained using FFE sequence due to missing MPRAGE data. All the other images were acquired using MPRAGE sequence.

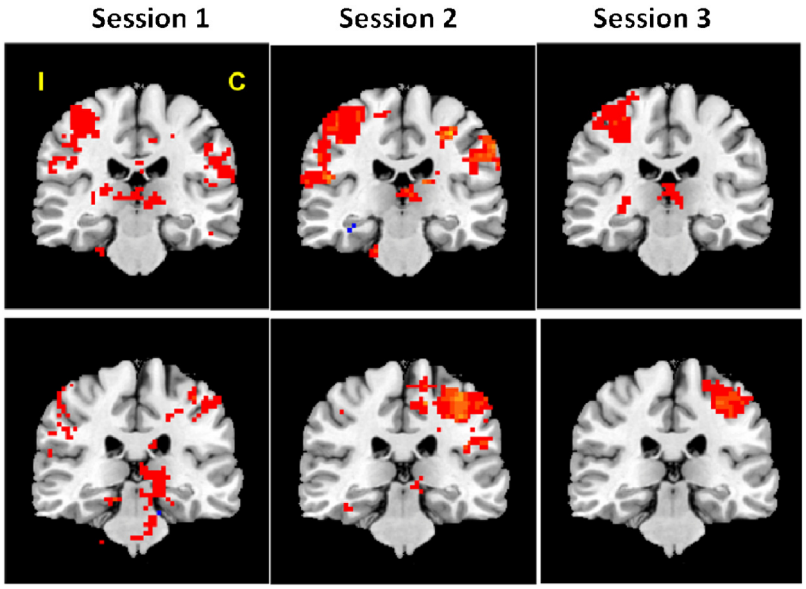


**Fig. 2.** Brain activation during movements of affected hand (top row) and unaffected hand (bottom row) in stroke patients ($p < 0.05$, corrected on the cluster level). First column: Session 1; middle column: Session 2; last column: Session 3.

motor recovery after BG lesion stroke offers valuable information for motor function rehabilitation.

In this study, we investigated the brain activation changes at different motor recovery stages for stroke patients with lesions specifically in BG regions. Blood oxygen level dependent functional magnetic resonance imaging (BOLD-fMRI) data were acquired to exhibit the activation level of human brain with exquisite spatial resolution [6]. There have been a battery of fMRI studies for stroke recovery investigation, including both cross-sectional and longitudinal ones [6–8]. Besides the lesion volume and initial stroke severity, it was shown that the early neuroimaging after stroke was of prognostic value of the motor recovery [8]. However, the