

Two types of sensory and motor cortical reorganization in hemiplegia following early cerebral damage: correlation of clinical outcome with neurophysiological and fMRI findings

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INTRODUCTION

Many physiological studies of motor recovery in hemiplegic cerebral palsy due to brain injury have identified the presence of novel corticomotor pathways. Only one physiological study has also investigated the afferent projections to sensory cortex and has shown that the predominant afferent projection of the affected hand is directed to the contralateral hemisphere. These preliminary findings indicate that there can be an interhemispheric dissociation between afferent kinesthetic inputs and efferent corticomotor output. Moreover, it is not clear if there exists any correlation between type of reorganization and outcome of sensorimotor function. This is in part due to the fact that in previous studies, plegic hand motor function was not evaluated with standardized criteria. By using clinical, somatosensory evoked potential (SEPs), transcranial magnetic stimulation (TMS) and functional magnetic resonance imaging (fMRI) methods, we investigated cortical sensorimotor reorganization of affected hand in patients with hemiplegic cerebral palsy.

MATERIAL AND METHOD

We recruited 15 patients suffering from mild to moderate hemiplegic cerebral palsy due to brain lesions originated at different ages. Hand motor impairment was graded according to the results at Melbourne test (0-100%); assessment of mirror movements (MM) was based on standardized criteria. TMS was delivered with a magnetoelectric stimulator (Magstim 200, UK) through a figure 8-shaped coil with twin 70 mm mean diameter loops which provides a focal stimulus at their intersection (peak magnetic strength, 2.2 Tesla, here designated as 100% intensity). The coil was positioned with its handle pointing along the sagittal axis and the center lying flat on the scalp. Electromyographic (EMG) responses were recorded from surface electrodes placed over opponens pollicis (OP) muscles bilaterally and amplified using a bandpass of 50 Hz and 3 kHz; the responses were recorded for 100 ms. MEPs were recorded during a monitored low-level contraction of both OP muscles. They were obtained by TMS over the optimal scalp position of each motor cortex with an intensity of 10% above the MTh. Cortical MEP latencies were recorded from the stimulus to the onset of the response, and measured from a superposition of at least 3 traces. SEPs were also recorded from frontal, centro-parietal, parietal and occipital regions, at the level of the seventh cervical spine, and from Erb's point. The median nerve was stimulated at the wrist with electric pulse of 0.1 msec in duration at the rate of 1Hz, with an intensity adjusted to obtain slight thumb twitches. MRI and fMRI examinations were performed on a 1.5 T MR scanner equipped with echo-speed gradient coils and amplifier hardware (GE, Signa Horizon 1.5). BOLD images were acquired by a EPI-GRE sequence (TR/TE=3000ms/50ms, matrix=128x128, FOV=28 cm x 28 cm). The acquired volume consisted of 10 contiguous 5 mm thick axial slices. Time-course series of 64 images for each volume were collected. Each period of the block design (30 sec task and 30 sec rest) was repeated three times. The first epoch always lasted 4 acquisitions (12 s) more to allow the signal to stabilise and this initial period was eliminated from any successive analysis. BOLD images were acquired during different types of activation tasks, one motor and one sensory for each hand. In the motor task, the subjects sequentially moved single fingers in opposition to the thumb. In sensory task, palm and fingers were passively brushed by an external operator with a wooden spatula. A volumetric set of high resolution images were acquired with a 3D FSPGR sequence (TR/TE=12ms/2.5ms; TI=700ms; 128 axial images, 1.1x1.1x1.1 mm³ voxel). These images were post-processed in order to identify the extension of lesion and to generate a 3D whole brain reconstruction to estimate the anatomical localisation of activated regions.

RESULT AND DISCUSSION

We identified 2 groups of patients on the basis of plegic hand motor skills: patients with mild impairment of affected hand (MI), and patients with moderate impairment (MOI). In MI group, MEPs and subsequent silent period (SP) in the paretic hand were still elicitable by TMS of the affected (contralateral) hemisphere, indicating that the primary motor representation of the paretic hand had not changed. SEPs of affected hand evoked short latency cortical components in the contralateral hemisphere and sensory fMRI protocol showed increased cortical activation in the affected hemisphere demonstrating that the primary somatosensory function of the affected hand is preserved (perilesional reorganization). In some patients of MI group, motor response in the affected hand could be elicited by TMS of both hemispheres. This demonstrated partial integrity of the crossed cortico-spinal tract and the presence of abnormal, ipsilateral projection. Thus these patients possess alternative pathways from both hemispheres to control the paretic hand. In MOI group, motor responses in the paretic hand were only elicitable by TMS of the unaffected hemisphere, so that the primary motor representation of the paretic hand was abnormally located in the unaffected hemisphere. fMRI demonstrated increased cortical activation in the unaffected hemisphere. Nevertheless, SEPs of affected hand evoked short latency cortical components in the contralateral hemisphere and sensory fMRI protocol showed increased cortical activation in the affected hemisphere. These results demonstrate that the afferent projection is directed to the affected hemisphere, resulting in dissociation between the hemisphere receiving kinesthetic inputs and providing motor outputs (dissociated reorganization).

In conclusion, this study shows that in patients with hemiplegic cerebral palsy, independently from etiology, better sensorimotor outcome is associated with perilesional reorganization of primary motor area, while worse outcome is associated with ipsilateral reorganization of motor function and contralateral sensory function.