Postoperative changes on functional mapping of the motor cortex in patients with brachial plexus injury: comparative study of magnetoencephalography and functional magnetic resonance imaging

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Abstract Using magnetoencephalography (MEG) and functional magnetic resonance imaging (f-MRI), we investigated the areas of the cerebral cortex that were activated when patients with brachial plexus injuries performed elbow flexion, a motion re-acquired through nerve transfer surgery. In all patients, elbow flexion on the operated side and on the unaffected side led to the activation of an area in the motor cortex, with these areas being located almost symmetrically on either side of the sagittal midline. These findings suggest that the activity center for the transferred intercostal nerves shifted to the motor cortex for the elbow, from the original intercostal nerve site.

Key words Magnetoencephalography · Functional magnetic resonance imaging · Brachial plexus injury · Intercostal nerve transfer

Introduction

Recent advances in methods of assessing neuropsychological function, such as magnetoencephalography (MEG), functional magnetic resonance imaging (f-MRI), and positron emission tomography (PET), have resulted in many reports on the localization of various information-processing areas,1–3,8,11 with attention having been focused on changes in the cerebral cortex accompanying environmental and growth-related events, which reflect the plasticity of the central nervous system.7,9,12,13 In the present study, we examined how the primary motor domain of the cerebral cortex responded to peripheral nerve transfer in patients who underwent intercostal nerve transfer after brachial plexus injury. Using MEG and f-MRI, we investigated which areas of the cerebral cortex were activated when

the patients performed elbow flexion, a motion that was re-acquired after nerve transfer surgery. The activity of both hemispheres, corresponding to the treated and unaffected side was assessed, and the localization of cortical activity on MEG and f-MRI was also compared.

Subjects and methods

The subjects were four patients who sustained brachial plexus injuries and who regained elbow flexion after intercostal nerve transfer (Table 1). Each subject was fully informed about the experimental procedures and consented to the study. All subjects were treated by one surgeon (N.O.) at Kanto Teisin Hospital (cases 1–3) or Izu Teisin Hospital (case 4). All subjects were injured in motorcycle accidents, and all had complete brachial plexus injuries with C5-T1 root avulsion. While each patient flexed the elbow on the operated or unaffected side, MEG was performed, and the source of the motor potential was estimated on MR images. Similarly, f-MRI was performed during elbow flexion of either the unaffected or treated sides, and the areas showing activation in the primary motor domain of the cerebral cortex were observed.

MEG measurement

MEG was performed in a magnetically shielded room at the NTT Comunication Science Basic Research Institute, using a superconducting quantum interference device (SQUID) gradiometer, model 122 (Neuromag, Helsinki, Finland). The patient performed elbow flexion on the operated side and the unaffected side alternately, at 4- to 5-s intervals. A laser trigger was used to sense elbow movement, and MEG was performed from 2 s before flexion to 0.3 s after flexion. The readings for 50 flexions were averaged. Each patient performed the study after receiving a detailed explana-
tion and carrying out practice. Neuromagnetic signals were filtered with a bandpass of 0.1 to 200Hz, isofield maps were produced at 1-ms intervals, and the current dipoles of the readiness potentials and motor potentials were calculated using the spherical volume conductor model. The source of this motor potential was estimated using computer software (Neuromag 122 X-fit; Neuro-mag, Helsinki, Finland), and its location was mapped on an MR image prepared in advance.

f-MRI imaging

Motor task. Each patient was asked to flex an elbow. The task consisted of 30s of rest and 30s of flexion movement, and was performed three times in succession. The patient was asked to imitate the examiner and to perform movements identical to those performed by the examiner. The task was performed only after a detailed explanation was given and the subject practiced.

Imaging method. f-MRI was performed by the echo planar imaging (EPI), technique using a 1.5-tesla machine (VISART-EX; Toshiba, Tokyo, Japan). T2-weighted images were obtained (TR, 1000 ms; TE, 40 ms, flip angle, 70°; matrix, 96 × 128; and field of view [FOV], 220 mm) in the horizontal plane parallel to a line joining the anterior commissure and the posterior commissure (AC-PC line). The distance from the midline to the center of activity on the scatter plot was measured directly on the MR image, using a reduced scale.

Results

MEG

In all patients, a slow magnetic field shift was observed over the contralateral hemisphere, starting about 500ms prior to the onset of movement. This was termed the readiness field (RF), corresponding to that described by Deecke et al. (1982), and was similar to the “readiness potential” that Deecke et al. reported in 1969 (Fig. 1).

A neuromagnetic field was observed over the contralateral hemisphere from 50ms before to 30–50ms after movement onset, and this was termed the motor field (MF), corresponding to that described by Kristeva et al. (1991) and being similar to the “motor potential” reported by Deecke et al. (1969) (Fig. 1).

Magnetic fields were calculated from the MF generated by elbow flexion on the operated side and the unaffected side in all patients. Based on the equivalent

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All patients showed root avulsion
Rt, Right; C, cervical spine; T, thoracic spine; musculocutaneous n., musculocutaneous nerve; MMT, manual muscle testing; MEG, magnetoencephalography; f-MRI, functional magnetic resonance imaging