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Reorganisation of the somatosensory system after early brain damage

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Abstract

Objective: To examine the reorganisation of the somatosensory system after early brain lesions.
Methods: We studied 12 young patients with congenital hemiplegia. Causative lesions were brain malformations, periventricular injuries and cortico-subcortical lesions. We explored the somatosensory system using evoked potentials, fMRI during sensory stimulation and clinical assessment of sensory function. To correlate sensory and motor function, we also performed transcranial magnetic stimulation, fMRI of hand movement and assessment of motor function by means of Melbourne test.
Results: Eleven patients showed a perilesional reorganisation of primary somatosensory function, as expressed by short latency potentials following stimulation of the paretic hand; in a remaining patient, delayed latency responses (N27.1) were only elicited over the ipsilateral undamaged hemisphere. Five of the eleven patients with perilesional somatosensory representation of the affected hand showed contralesional shifting of motor function, thus exhibiting sensory-motor dissociation. Significant correlation was found between sensory deficit and fMRI activation during sensory stimulation.
Conclusions: In subjects with early brain lesions, somato-sensory function is generally reorganised within the affected hemisphere. A contralesional shifting is uncommon and poorly efficient in function restoration.
Significance: This study confirms and further explores the difference in reorganisation capabilities of the motor and sensory system following early brain injury of different etiologies and timing.

Keywords: Somatosensory system; Primary sensory cortex; fMRI; SEPs; Melbourne test

1. Introduction

Brain injuries affecting the sensorimotor system may lead to various degrees of functional impairment, which is related not only to the location and extent of the lesion, but also to the type of adaptive reorganisation of the nervous system. Observations in animals and humans have shown the complexity of these mechanisms that may consist either in a functional compensation coming from spared structures or in a restoration/rebuilding of those that are damaged, or both (Chen et al., 2002; Green, 2003; Butefisch, 2004; Seitz et al., 2004).

As far as the motor system is concerned, the main mechanism for a reconnection of the motor cortex to the spinal cord consists of a reorganisation within the ipsilesional cortex, in regions inside the primary motor cortex (M1), or in non-primary motor areas (Boyeson et al., 1994). This type of reorganisation is based on the multiple representation of the body inside M1 or on the possibility that functions, formerly assumed by the primary motor cortex, may also be taken over by remote and intact non-primary motor areas within the damaged hemisphere (Boyeson et al., 1994; Donoghue et al., 1996; Nudo and Milliken, 1996; Hallett,

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2001). A reorganisation at the level of the unaffected hemisphere is also common, consisting in the disinhibition or unmasking of ipsilateral cortico-spinal pathways, which have been interpreted as due to longer latency oligosynaptic connections (Benecke et al., 1991; Netz et al., 1997; Ziemann et al., 1999). When the lesion occurs at an early stage of development, either during the intrauterine life or soon after birth, a different mechanism can also be observed (Carr et al., 1993; Eyre, 2003; Staudt et al., 2002, 2004). It is based on the persistence of a significant contingent of monosynaptic fast-conducting ipsilateral motor projections that, in normal conditions, withdraw during later development, but may be permanently maintained if a brain damage occurs early in life (Carr et al., 1993; Maegaki et al., 1997; Eyre et al., 2001).

While the reorganisation of the motor system after early brain damage has been extensively investigated using electrophysiological and neuroimaging techniques, little is known about the reorganisation of the somatosensory system in these patients. Most studies support the hypothesis of an intra-hemispheric (ipsilesional) reorganisation of primary somatosensory area as the main compensatory mechanism following brain damage, even when occurring early in life (Rossini et al., 2001; Burneo et al., 2004; Staudt et al., 2006a). In some children with congenital hemiplegia, an interhemispheric (contralesional) reorganisation was suspected on the bases of ipsilateral somatosensory evoked potentials (SEPs) of the paretic hand, that however always showed abnormally prolonged latencies more compatible with non-lemniscal sensory conduction (Bernasconi et al., 2000; Holloway et al., 2000; Ragazzoni et al., 2002). The only evidence of a true interhemispheric reorganisation of the primary somatosensory region, i.e., the existence of ipsilateral short-latency SEPs after stimulation of the paretic hand, was provided by Maegaki and co-workers in a patient with extensive unilateral cortical dysplasia (Maegaki et al., 1995). This type of lesion has an early gestational origin, thus suggesting that inter-hemispheric reorganisation of the primary sensory system might be possible if cortical damage occurs during early brain development.

A difference in reorganisation capabilities between motor and sensory function has been recently confirmed in four children with congenital hemiplegia who showed a hemispheric dissociation between ipsilaterally reorganised motor function and contralaterally preserved somatosensory function (Staudt et al., 2006a). In all these cases, hemiplegia was due to unilateral periventricular damage, which occurred during the early third trimester of gestation.

In order to explore the reorganisation mechanisms in a wide spectrum of conditions in terms of timing of the lesion, we selected a group of children with congenital hemiplegia secondary to different types of brain injury whose timing could be assigned to different pre-natal or early postnatal periods and we investigated the reorganisation of the somatosensory system using a combination of clinical, neurophysiological and fMRI methods.

The specific aims of the study were to explore the type of reorganisation of the somatosensory system, the correlation between sensory deficit and type of reorganisation and between sensory and motor deficits, in relation to the type of reorganisation.

2. Methods

Twelve patients with congenital or early acquired hemiplegia (4 females; age range: 10–28 years; mean age: 16.8 years) were selected for this study. In order to ensure a good compliance for clinical, neuroimaging and electrophysiological assessments, patients included in the study had to be at least ten years old and cognitively normal or only mildly delayed.

The study was approved by the Ethical Committee of the Stella Maris Scientific Institute of Pisa.

2.1. Clinical assessment

To assess the quality of upper-limb motor function, we administered to all patients the Melbourne Assessment of Unilateral Upper Limb Function (Johnson et al., 1994). The test consists of 12 items selected with the aim of evaluating quality, range, target accuracy and fluency of movement. Scoring ranges from 0% to 100%, the latter indicating the best performance.

Clinical assessment of sensory deficits was performed according to the criteria of Uvebrant, modified (Uvebrant, 1988). The aspects evaluated in the affected hand were tactile sense, pain and joint position sense, stereognosis, graphaesthesia and two-point discrimination. A three-point score was used for each item (Table 1), score 3 indicating the worst response.

2.2. TMS

TMS was delivered with a magnetoelectric stimulator (Magstim 200, UK) through an 8-shaped coil with twin 70 mm mean diameter loops providing a focal stimulus at their intersection (peak magnetic strength 2.2 T, here designated as 100% intensity). The coil was positioned with its handle pointing along the sagittal axis and the centre (the intersection of the loops) lying flat on the scalp so that it was in contact with the scalp and close to the target. Electromyographic (EMG) responses were recorded from surface electrodes placed bilaterally over *opponens pollicis* (OP) muscle. The responses were recorded for 100 ms and the signal was amplified using a bandpass of 50 Hz and 3 kHz. Patients were comfortably seated wearing a skullcap fixed with reference to inion, nasion, ears. Over the skullcap all positions of the 10–20 International System were indicated.

Initially, both hemispheres were explored for stimulation points eliciting contralateral and/or ipsilateral motor evoked potentials (MEPs) in the target muscle. Scalp sites were explored over each hemisphere in a 1-cm grid and