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A recovery from enhancement of activation in auditory cortex of patients with idiopathic sudden sensorineural hearing loss

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Abstract

Objective: We previously reported enhanced activation of auditory cortex in patients with bilateral chronic inner-ear hearing loss. To determine whether this enhancement can exhibit a short-term alteration, we measured auditory evoked magnetic fields (AEFs) in patients with idiopathic sudden sensorineural hearing loss (ISSHL) in the acute phase (AP) and recovery phases (RPs).
Methods: We recorded AEFs in two unilateral ISSHL patients at three time points (AP, RP1, and RP2) using a whole-head neuromagnetometer. Tone bursts of 1 kHz were presented monaurally to the affected and healthy ear at four different intensities (40–70 dB HL).
Results: Both patients showed the enhancement of N100 m moment at AP and not at RPs in response to the affected ear stimulation, and stronger N100 m moment in ipsilateral than contralateral hemisphere in response to the healthy ear stimulation at AP.
Conclusions: Enhancement of N100 m amplitude occurs in ISSHL patients and disappears on the scale of days. Enhancement of activity in the auditory cortex derived from inner-ear hearing loss can thus exhibit short-term change.
Significance: The results of this study provide first evidence for a recovery from enhancement of activation in the auditory cortex following injury of peripheral hearing organ.

Keywords: MEG; Inner-ear hearing impairment; Sudden sensorineural hearing loss; N100 m; Auditory cortex

1. Introduction

We previously reported that the dipole moment for auditory N100 m, a representative long-latency response in the auditory cortex, in patients with bilateral inner-ear hearing loss was larger and increased more rapidly as a function of stimulus intensity than in healthy subjects, despite loss of peripheral auditory function in the patients (Morita et al., 2003). It is unclear, however, whether this enhancement can exhibit short-term alteration.

In idiopathic sudden sensorineural hearing loss (ISSHL), loss of hearing occurs suddenly and hearing impairment develops within a short period of time. Lesions of the cochlea are thought to be responsible for it (Merchant et al., 2005). Two ISSHL patients who exhibited complete recovery of hearing participated in this study. To determine whether the enhanced activation in auditory cortex accompanying inner-ear hearing loss can exhibit short-term alteration, we measured auditory evoked fields (AEFs) in the acute phase (AP) and recovery phases (RPs) and compared them with those in two groups (healthy subjects and those with permanent impairment of inner-ear hearing) examined in our previous study (Morita et al., 2003).

Parts of this study have been published previously in abstract form (Morita et al., 2004).

2. Methods

2.1. Subjects

Two patients with ISSHL were studied. They suffered from sudden profound unilateral hearing loss and visited the Otolaryngology Department of Kyoto University Hospital at 2 and 6 days after the onset of their hearing loss, respectively. We detected profound idiopathic unilateral sensorineural hearing

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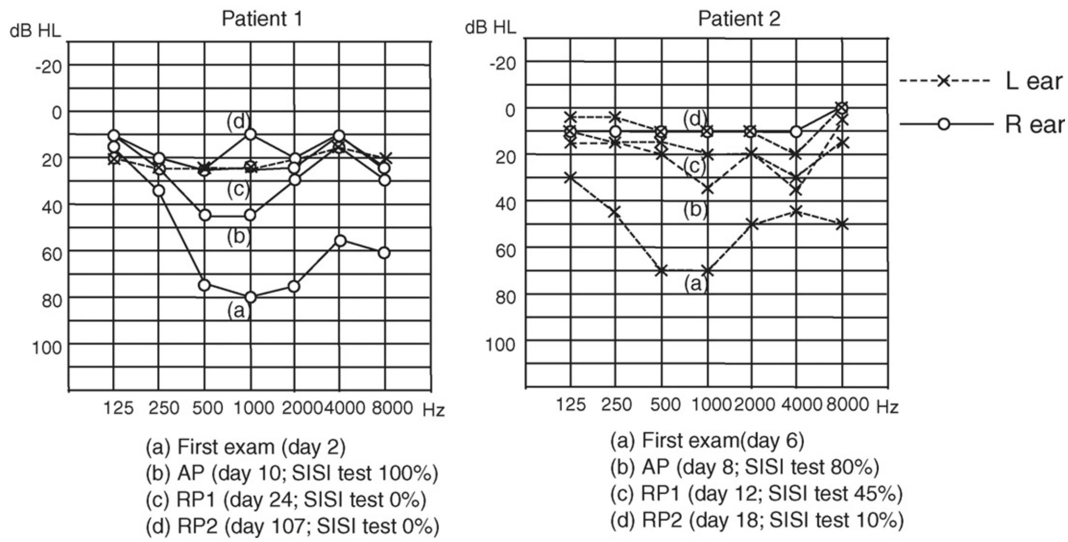

Fig. 1. The course of change in hearing thresholds in the two patients. Both patients exhibited profound hearing loss at the first exam, and complete recovery at the last exam.

loss and treated them with intravenous adrenocorticosteroid injection (prednisolone 200 mg/day for 3 days, 150 mg/day for 3 days and 100 mg/day for 3 days). They exhibited no neurological disorder other than hearing loss. Whole head MRI (magnetic resonance imaging) tests targeting cerebello-pontine angle and internal auditory meatus were performed during the treatment, and revealed no abnormal findings. The courses of change in their hearing thresholds are presented in Fig. 1. Each patient finally exhibited complete recovery from hearing impairment. We measured their AEFs at three different time points: Patient 1 (62-year-old female: right ear affected) at days 10, 24, and 107 after disease onset, and Patient 2 (37-year-old male: left ear affected) at days 8, 12, and 18. Loudness recruitment, which is better-than-normal capability for detecting small increments of sound intensity change and a characteristic finding of inner-ear hearing loss, was observed at AP (day 10 in Patient 1, day 8 in Patient 2), but disappeared before day 24 in Patient 1 and before day 18 in Patient 2. The short increment sensitivity index test (SISI) was employed to determine loudness recruitment phenomenon, which consisted of a continuous tone for 100 s at 20 dB above the hearing threshold with 20 sporadic 1 dB increments of sound intensity lasting for 200 ms (Jerger et al., 1959). In this study, SISI test $\geq$70% and $<$30% at 1 kHz were considered recruitment phenomenon-positive and -negative, respectively. Both patients were right-handed. Both patients gave informed consent to participate in this study. This study was approved by the Committee of Medical Ethics of the Graduate School of Medicine and Faculty of Medicine, Kyoto University (Protocol No. 111).

2.2. Stimuli and measurements

We used the same stimulus as in our previous study (Morita et al., 2003). A 1-kHz pure tone was presented monaurally to the affected ear or healthy intact ear in different sessions through a plastic tube and foam earpiece. The duration of the sound stimulus was 200 ms (15 ms linear rise/fall times), and intensity was set at 40, 50, 60, or 70 dB HL (hearing level) measured at the end of the plastic tube. These sounds of four different intensities were presented randomly and equiprobably to the tested ear in each session with a constant interstimulus interval (ISI) of 1-s. Masking noise to the opposite ear was not used. Recordings were performed in a magnetically shielded room (NKK, Yokohama, Japan) where the subjects were seated under a helmet-shaped dewar. We instructed the subjects to ignore the stimuli.

AEF was recorded with a 122-channel whole-head DC-SQUID (Superconducting QUantum Interference Device) magnetometer (4D Neuroimaging Ltd., Helsinki, Finland). The recording passband was 0.03–130 Hz, and data were digitized at 419 Hz. The period of analysis was 950 ms, from 150 ms before to 800 ms after stimulus onset. The 100 ms pre-stimulus segment was used as the baseline for amplitude measurement. The vertical electro-oculogram (EOG) was simultaneously recorded by placing electrodes in the supra- and infraorbital regions of the left eye to exclude epochs contaminated by eye movements or blinks. The epochs coinciding with EOG or MEG changes exceeding 150 μV or 3000 fT/cm, respectively, were excluded from on-line averaging. One hundred epochs were averaged for each stimulus. Location of the head with respect to the sensors was determined by measuring the magnetic fields produced by small currents delivered to four coils attached to the scalp. Location of the coils with respect to the preauricular points and the nasion was measured with a three-dimensional digitizer to permit alignment of the MEG and MRI coordinate systems. We accepted only data from the sessions in which the variance of position of four coils and that of distance between every combination of two coils was less than 5 mm.

2.3. Data analysis

The averaged responses were low-pass-filtered digitally at 40 Hz. Both subjects underwent three-dimensional MR imaging using a 0.2-T Signa Profile system (General Electric Medical Systems, Milwaukee, USA). A single sphere model was used for the source modeling. Each subject's sphere was determined from his or her own MRI data. Two equivalent current dipoles (ECDs) were used to explain the magnetic field distribution. First, a single ECD for the component around 100 ms after the stimulus onset (N100 m) was identified in each hemisphere separately. A subset of 18 channels around the signal maximum of N100 m in each hemisphere was selected and the best fit of ECD was obtained by a least-squares search at the latency of peak amplitude (Hamalainen et al., 1993). We accepted only ECDs with goodness-of-fit $>$80%. Finally, the period of analysis and selection of channels were extended to the entire time range and all 122 channels, and the optimal temporal changes of the dipole waveforms were computed, allowing their strength to change while keeping the locations and orientations fixed as determined by the fit at N100 m. The dipole moment for N100 m for each hemisphere was represented by their largest values around the peak latency.

3. Results

3.1. Auditory evoked fields

Fig. 2 shows responses to the stimulation of affected ear from the channels showing the largest amplitudes over the temporal areas in the contralateral hemisphere with four different sound stimulus intensities in each measurement for