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Temporo-parietal theta activity correlates with misery perfusion in arterial occlusive disease

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ABSTRACT

Objective: Temporo-parietal theta activity (TPTA), often detected in hemispheres with internal carotid (ICA) or middle cerebral artery (MCA) occlusive lesions, is more clearly separated from occipital alpha activity by magnetoencephalography (MEG) than electroencephalography. The present study investigated whether TPTA is correlated with misery perfusion, a surgically correctable type of hemodynamic impairment.

Methods: Awake MEG was measured in 56 patients with ICA or MCA occlusive lesions. Regional cerebral blood flow (rCBF) and regional cerebrovascular reactivity (rCVR) to acetazolamide were measured in the MCA territory by xenon-133 single-photon emission computed tomography. MEG was repeated in 10 patients after vascular reconstruction surgery.

Results: Fourteen patients showed TPTA in the lesion hemisphere ($n = 13$) or bilaterally ($n = 1$). The presence of TPTA was significantly correlated with both reduced rCBF and reduced rCVR ($P = 0.0009$). After surgery, TPTA disappeared in 7 of the 10 studied patients.

Conclusions: The presence of TPTA suggests misery perfusion, which is characterized by reduced rCBF and reduced rCVR.

Significance: MEG can detect the presence of reversible and surgically remediable cerebral ischemia before the development of complete infarction.

1. Introduction

Electroencephalography (EEG) often shows slow waves such as delta (below 4 Hz) and theta (4–8 Hz) activity in patients with cerebral infarction (Gloor et al., 1977; Ingvar et al., 1976; Nagata, 1989; Nagata et al., 1989; Steriade et al., 1990). Previous magnetoencephalography (MEG) studies have indicated that the slow waves are generated from the adjacent cortical areas, rather than the center of the infarct lesions (Kamada et al., 1997; Vieth, 1990). However, whether such slow waves can provide a warning sign of remediable ischemic conditions before completion of major infarction has not been demonstrated.

Recently, temporo-parietal theta activity (TPTA) at 6–8 Hz was identified in the hemisphere with internal carotid (ICA) or middle cerebral artery (MCA) occlusive lesions (Seki et al., 2005). Such TPTA was more clearly separated from occipital alpha activity by MEG than EEG due to the higher spatial resolution of MEG (Seki et al., 2005). TPTA was assumed to result from hemodynamic impairment, even at the reversible stage, because occlusion or stenosis of the major cerebral arteries leads to reduction of perfusion pressure in the distal circulation (Derdeyn et al., 1999; Powers et al., 1987). In fact, TPTA was not detected in 27 age-matched normal subjects (Seki et al., 2005). Moreover, the presence of TPTA was significantly correlated with ICA occlusive lesion regardless of the presence or size of the infarct lesions (Seki et al., 2005). However, the hemodynamic status has not been directly evaluated by positron emission tomography (PET) or single-photon emission computed tomography (SPECT).

Previous PET and SPECT studies have demonstrated that misery perfusion is a risk factor for cerebral ischemia (Grubb et al., 1998; Ogasawara et al., 2002; Yamauchi et al., 1996). Misery perfusion, a recoverable and treatable type of hemodynamic impairment, is evaluated by the hemodynamic status including cerebral blood flow (CBF), and oxygen metabolism or cerebral perfusion reserve. Misery perfusion is defined by reduction of CBF and increase of

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oxygen extraction fraction (OEF) as detected by PET (Baron et al., 1981). Misery perfusion can also be determined by cerebrovascular reactivity (CVR) to acetazolamide as measured by SPECT (Kuroda et al., 1993, 2001; Ogasawara et al., 2002), which correlates with the oxygen metabolism measured by PET (Kuroda et al., 2004, 2006).

The present study measured CBF and CVR by SPECT in patients with ICA or MCA occlusive lesions, to investigate whether TPTA in MEG is correlated with misery perfusion.

2. Methods

2.1. Patient selection

This study included 56 consecutive patients, 47 males and 9 females aged 40–75 years (mean ± SD 65.5 ± 7.0 years), who were admitted to assess the indications for vascular reconstruction surgery. All patients satisfied the inclusion criteria as follows: age not over 75 years; occlusive lesion of the ICA or MCA confirmed by digital subtraction angiography (DSA) more than 1 month after the last ischemic stroke event; modified Rankin Scale (van Swieten et al., 1988) better than grade 2; and DSA, magnetic resonance (MR) imaging, SPECT, and MEG completed within 2 weeks. Patients were excluded if hemorrhagic infarction, cardiogenic embolism, or tandem occlusive lesions of the ICA and MCA were located on the same side. This study was approved by the institutional ethics committee. All patients gave written informed consent.

Thirty-four of the 56 patients had a history of transient ischemic attacks or completed stroke. The clinical symptoms were minor (modified Rankin Scale better than grade 2) even in patients with completed stroke. Twenty-two patients had no history of stroke events but occlusive lesions were detected incidentally. Seventy-three of the 112 cerebral hemispheres harbored small or negligible infarct lesions shown to be lacunar infarction, or cortical or subcor-

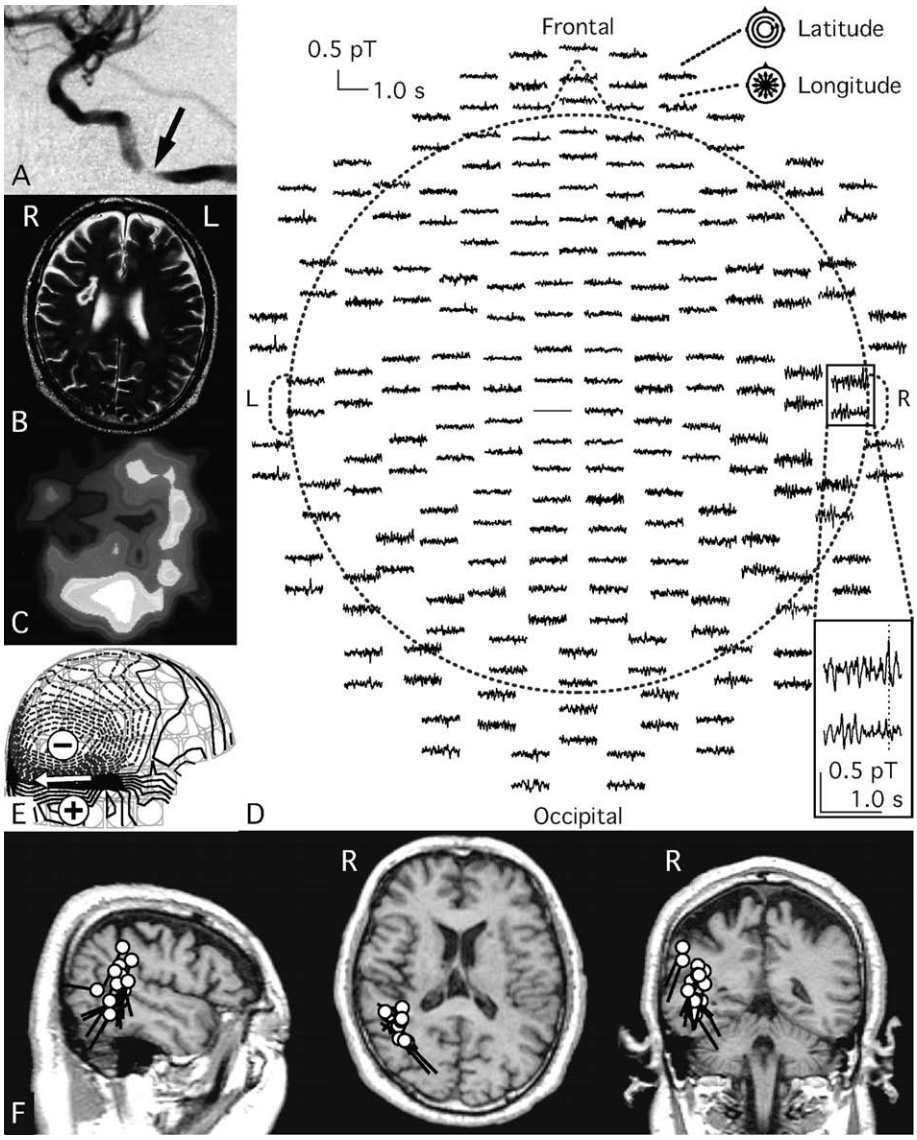

Fig. 1. Case 13. A 54-year-old male with typical temporo-parietal theta activity (TPTA) detected by MEG. (A) Digital subtraction angiogram showing stenosis (arrow) of the right internal carotid artery. (B) T2-weighted MR image showing a right striatocapsular infarct lesion. (C) SPECT scan showing flow reduction in the territory of the right middle cerebral artery. (D) MEG waveforms, detected in the awake condition with eyes closed using the latitudinal and longitudinal tangential derivatives of 204 planar-type gradiometers over the entire head (Ahonen et al., 1993), showing TPTA in the right hemisphere. (E) Isofield map at a typical peak of TPTA (broken line in the inlet square of D), showing a single dipole pattern. The arrow shows the approximate location and orientation of the equivalent current dipole (ECD) of TPTA over the right temporal area. (F) ECDs at 10 similar peaks of TPTA to (D) and (E) projected onto three orthogonal MR images. Circles and bars indicate the ECD location and orientation, respectively.