## Novel Application of EEG Source Localization in the Assessment of the Penumbra

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### Introduction

The ischemic penumbra has been operationally defined as the mismatch between transit time of contrast and low cerebral blood volume [1, 2]. Recently, authors have described the use of continuous electroencephalography (EEG) as an alternative method to monitor the ischemic penumbra [3]. This method has the drawback of not providing an image of the penumbra. In this case report, we describe a novel application of EEG source localization, using routine EEG data, to provide a topographical image of the ischemic penumbra.

### Method

EEG was performed using a skull-based cap according to the 10-20 system. Low-resolution electromagnetic tomography (LORETA) [4] computations were carried out to depict the current density map/neuronal activity on the cortical gray matter in a realistic 4-compartment model of the head that included the scalp, skull, cerebral spinal fluid and brain tissue. The sLORETA software [4] uses the digitized Montreal Neurological Institute 152 template for calculating the 3-dimensional localization of electrical activity in the brain. The current implementation of the sLORETA algorithm uses a total of 6,239 gray-matter voxels with a resolution of 5 mm$^3$ (available at http://www.uzh.ch/keyinst/loreta.htm). The lead field for this realistic head model was computed using the boundary element method [4, 5].

### Case Report

The patient is a 56-year-old female who presented with sudden onset of right-sided hemiparesis and aphasia. CT angiography showed evidence of occlusion of the left middle cerebral artery (fig. 1). The first EEG was performed as the patient was given a bolus of recombinant tissue-type plasminogen activator; this occurred 3.5 h after stroke onset. The patient made a dramatic clinical recovery after half an hour of recombinant tissue-type plasminogen activator administration. The National Institutes of Health Stroke Scale improved by 10 points (initial score was 12). Follow-up magnetic resonance angiography shows complete recanalization and infarction in the territory of the left middle cerebral artery.

### EEG and LORETA Findings

The initial EEG showed delta wave over the left frontotemporal region. The spectral analysis using sLORETA showed a large region of elevated electrical activity at low temporal frequencies (fig. 1, 2) in keeping with cortical regions with mean transit time greater than 4 s but showed no abnormalities in the temporal lobe (mean transit time <4 s) or deep gray-matter nuclei. This region was distinct from the infarct seen on the follow-up magnetic resonance scan. Two days after stroke onset, the EEG showed resolution of the delta wave over the left frontotemporal region.

### Discussion

This case report is the first description of the application of the EEG source localization method LORETA for the assessment of the ischemic penumbra. In our case both the EEG and the EEG source localization method provided similar data on the region of brain dysfunction. In this patient, the LORETA image underestimated the true extent of the perfusion deficit, particularly in the deep nuclei and the temporal lobe. These technical issues arise in early development of this software, and it is anticipated that in future versions these can be improved. The LORETA method has an advantage in that it offers a pseudoimage of brain activity and thus does not require an expert EEG reader. Furthermore, the abnormal EEG activity may be monitored continuously in real time, unlike conventional imaging techniques. A potential application of this method is in the area of recanalization of large artery occlusion. This paper describes an opportunistic chance to observe the evolution of arterial status and clinical deficit. It is a single case report, and thus the observation described here will require further study.
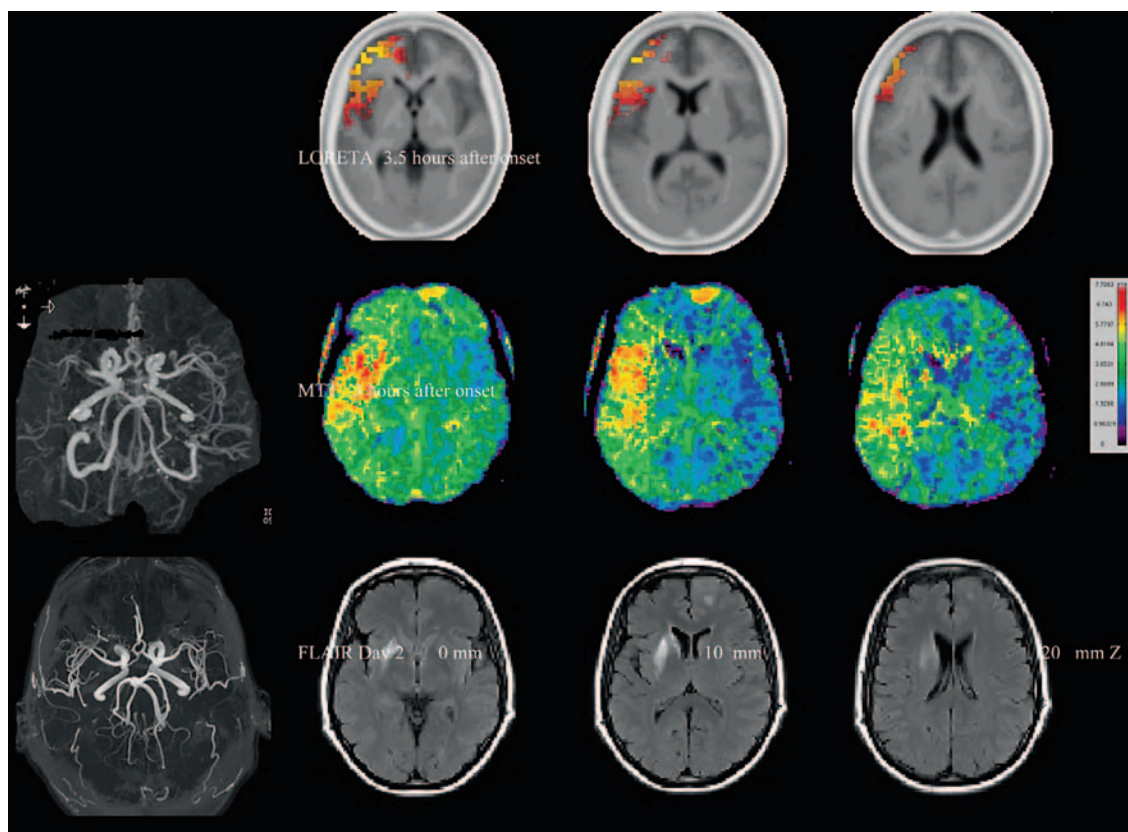
**Fig. 1.** The images are shown in neurological convention with the left side being on the left. The region of abnormal electrical activity on the LORETA images at 3.5 h underestimate the perfusion deficit seen in the mean transit time (MTT) image in the temporal lobe and striatocapsular region. Follow-up MRI fluid-attenuated inversion recovery (FLAIR) images on day 16 showed a left striatocapsular infarct but none in the left frontotemporal cortical region.
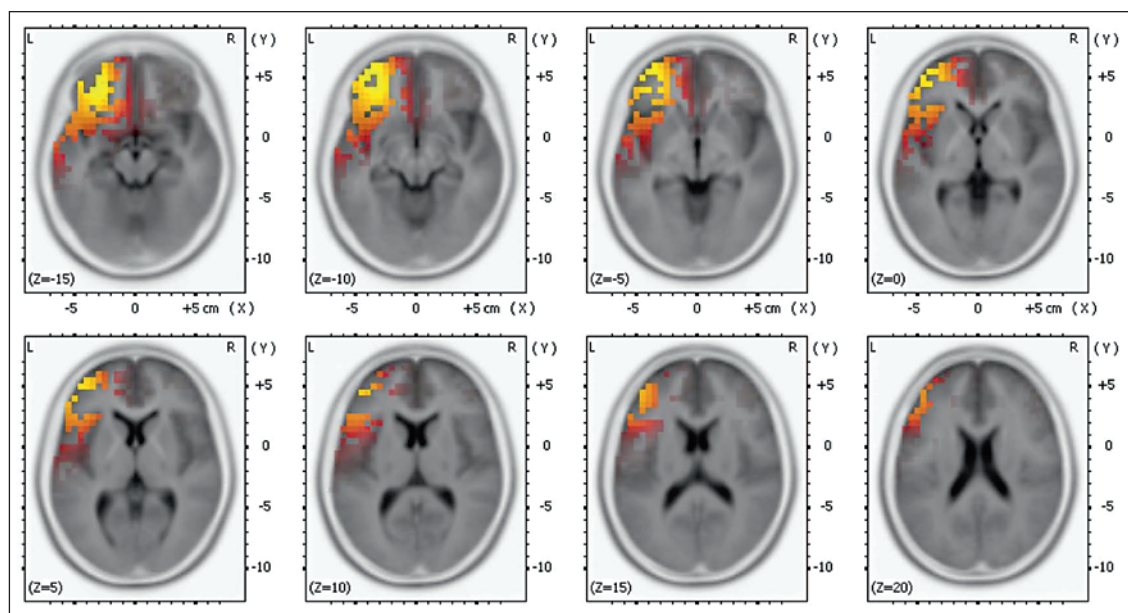


**Fig. 2.** The full extent of abnormal electrical activity on the LORETA images at 3.5 h.

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