Brain sodium accumulation correlates with electrical abnormalities in drug-resistant epilepsy: a 23Na MRI and intracranial EEG recording study

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Purpose: Patients suffering from pharmaco-resistant partial epilepsy are potential candidates for epilepsy surgery consisting of removal of the epileptogenic zone (EZ). The localization of the EZ during presurgical assessment is a crucial issue and often requires invasive intracranial EEG recordings. Therefore, developments of new non-invasive localizing methods are of particular interest in this context.

Concurrently, in animal models of epilepsy, sodium channels have been found to be altered, inducing sodium accumulation in regions involved by seizures. Brain sodium MRI can provide a non-invasive mapping of abnormal sodium accumulations and has been used in other neurological pathologies as a marker of neuronal suffering/degeneration.

In order to assess if brain sodium MRI can be a surrogate marker of the epileptogenic area in drug-resistant epilepsy, we assessed for the first time in this study the potential correlation between the abnormal quantitative sodium maps and the electrical alterations evaluated by intracranial recordings representing the current gold standard.

Methods: 8 patients with drug-resistant epilepsy were explored by MRI on a 3T system (Verio, Siemens, Erlangen, Germany) and 48h later by intracerebral electroencephalography (iEEG) recordings. Fifteen healthy controls were explored by MRI only.

23Na MRI was acquired using a double-tuned 23Na-1H volume head coil (Rapid Biomedical, Rimpar, Germany) and a density-adapted three-dimensional radial projection reconstruction pulse sequence (TE=200μs, TR=120ms, 17000 projections, acquisition time=34 min, nominal spatial resolution of 3.6x3.6x3.6mm3, with two external references filled with 50 mM of sodium and placed very close to the head for quantification). High-resolution 1H MRI was obtained with a 3D-MPRAGE sequence (TR=2300ms, TE=3ms, TI=900ms, FOV=256x256x256, 160 slices, 1x1x1mm3 of resolution) using a 32-element 1H head coil (Siemens).

iEEG was performed 48h after the MRI exploration using multiple contact depth electrodes (10–15 contacts, length: 2 mm, diameter: 0.8 mm, spaced 1.5 mm apart) positioned according to Talairach’s stereotactic method. After implantation of the intracranial electrodes, a MPRAGE sequence was performed. iEEG signals were recorded on a 128 channels system (DeltamedTMH, France) during interictal periods and allowed to assess the number of spikes and the epileptogenic index (EI).

Results: By using a statistical threshold of p<0.005 for which no significant cluster survived when comparing any individual control with the whole population of controls (two-sample t-test, SPM8), we observed significant sodium accumulation in all patients with the abnormal TSC increases.

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Conclusions: These results demonstrate for the first time that abnormal accumulation of sodium concentrations succeeded to lateralize epilepsy and that the sodium concentrations in the GM of patients suffering from drug-resistant epilepsy are correlated with the interictal electrical abnormalities in the regions that are the most prone to be part of the epileptogenic zone. Brain sodium MRI appears as a promising non-invasive presurgical tool in drug-resistant epilepsy.