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Detecting neuronal currents directly by low field NMR: a phantom study

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Introduction

Today's neuroscience and neurological diagnostics may benefit from the precise knowledge of the temporal and spatial distribution of neuronal currents. As the possibility to detect neuronal currents by high field NMR techniques directly remains controversial, low field NMR promises to be an alternative. In low field MRI the utilization of a resonant and a direct current (DC) mechanism has been proposed.

Methods

For the DC effect the superposition of the neuronal field (hundreds of pT) and the detection field (~ µT) might lead to a detectable alteration of the NMR signal of the brain region around the active neurons. We emulated a sustained neuronal activity by means of a single dipolar source in a physical phantom. The phantom consisted of a hollow sphere made of PVC filled with a aqueous solutions of NaCl and CuSO4. By adjusting the concentration of CuSO4 the nuclear relaxation times could be tuned to the value for brain matter (~100 ms). Inside the sphere an electric current dipole was mounted, which was made from two insulated twisted copper wires with non-insulated platinum endings.

Results

In order to resolve the minute changes of the NMR signal due to the operation of the dipole we found that the subtraction of a reference signal (phantom not operated) is necessary. After such a processing, initial measurements with polarization fields of up to 5 mT showed that the minimal detectable evoked current dipole moments in the phantom were up to 2 orders of magnitude higher than the physiologically observed values.

Conclusion

The required increase of the signal to noise ratio to make the detection of neuronal currents feasible can be achieved by technical improvements. These include the design and construction of a low noise dewar and the implementation of hardware enabling the application of polarizing fields of up to 50 mT.