Simultaneous single unit and BOLD fMRI recordings

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Introduction

Simultaneous single unit recording and BOLD-contrast functional MR imaging provides complementary information on both spontaneous and induced neuronal activity. However, the restrictions of each method produce a unique set of problems when they are combined. Implanted electrodes create artifacts in the MR images due to differences in magnetic susceptibility between the tissue and electrodes. Depending on the size and type of the electrode used, these artifacts may entirely obliterate the BOLD signal.
MR imaging, on the other hand, introduces additional noise into the electrophysiological signal, making the analysis difficult. This noise has contribution from gradient-dependent and gradient-independent components.
Here we investigate experimental approaches to minimize these mutual interferences. Combination of fMRI and in vivo electrophysiology is used to record hemodynamic functional signal and the corresponding neuronal activity in an awake, behaving rabbit. Different types of electrodes are evaluated for the presence of artifacts and the quality of single unit recordings with a somatosensory activation paradigm.

Methods

Dutch-Belted rabbits were chronically implanted with manipulators containing a microwire electrode made of platimun-iridium, platinum-tungsten or gold-silver aimed at the whisker barrel cortex. MR imaging experiments were performed on a 4.7T or 9.4T Bruker BioSpec imaging spectrometers. Functional imaging data (220µm x 220µm in plane) were acquired from four consecutive slices (1 mm thick), using a single-shot gradient-echo EPI pulse sequence (TR=2s; TE=13ms for 9.4T and TE=20ms for 4.7T). High-resolution gradient-echo images (55µm x55µm in plane) were also acquired to visualize the electrode position. The imaged slices covered the entire whisker cortex. Awake rabbits were restrained using stereotaxically implanted headbolts as described previously (1). Whiskers were stimulated at 75 Hz frequency, using the following paradigm: 50s off - 40s on -40s off. Ten trials were acquired. Neuronal activity was recorded using Neuralynx system.

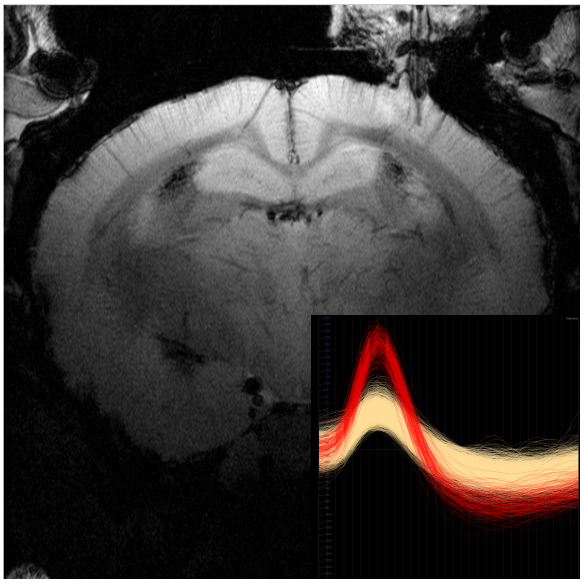

Fig. 1. Gold/silver electrodes (4x25 µm each) are visualized in the GRE image, obtained on 9.4T, with insignificant susceptibility artifacts. Tips of the electrodes are located in the layer IV of cerebral cortex.
In the lower right corner two waveforms of single unit action potentials, recorded with the same electrodes, are shown. There are two very well separated units. The excellent shape of waveforms indicates very good quality of recording system.

Results

Of the three electrodes evaluated the gold/silver electrode produced minimal distortions, followed by platinum/tungsten. A platinum/iridium electrode showed the biggest artifact of the three. In addition to the absence of artifacts, the gold/silver electrode has good impedance and yields good quality of the signal (Fig. 1).
Gradient-dependent noise irretrievably corrupted the electrophysiological data during time intervals of gradient pulses. Therefore, blocks of gradient interference were removed prior to data analysis. High frequency gradient-independent noise occurred very often during electrophysiological recording but was much smaller then our signal of interest. The gold/silver electrode recorded spikes with very good signal/noise ratio, and did not interfere with the quality of the BOLD signal.

Conclusions

Our methodology allows simultaneous recordings of neuronal and BOLD signals at high magnetic fields (4.7T, 9.4T) with excellent delineation of single neuron activity in somatosensory cortex, and BOLD activity detected close to the electrodes.

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1. Wyrwicz A.M. et al., Magn. Reson. Med. 44: 474-478 (2000).