High-resolution 3D MRI visualizes chronic microelectrodes in the brainstem of the squirrel monkey without the risk of lesions

R. Tammer[1], L. Ehrenreich[1], S. Boretius[2], T. Watanabe[2], J. Frahm[2], T. Michaelis[2]

[1]Neurobiology, Deutsches Primatenzentrum GmbH, Goettingen, Lower Saxony, Germany, [2]Biomedizinische NMR Forschungs GmbH am MPI für biophysikalische Chemie, Goettingen, Lower Saxony, Germany

Introduction

MRI has been successfully applied to guide the placement of electrodes in individual monkeys [1,2]. However, to confirm the precise electrode position its direct visualisation is essential. This is particularly important in neuroethological telemetric experiments in freely moving squirrel monkeys [3] and if very small mesencephalic brainstem structures are to be investigated. The purpose of this study was (i) to evaluate the MRI compatibility of a novel self-made electrode and microfeed equipment, (ii) to determine the exact position of the electrode tip relative to the neuronal target structure with high-resolution 3D MRI, and (iii) to ensure that the applied magnetic field strength in conjunction with the used MRI techniques induces no lesions at the recording site.

Methods

A quartz glass insulated platinum-tungsten microelectrode (metal core 25 µm, shank o.d. 80 µm, above tip o.d. 40 µm) was inserted into two telescoping boro-silicate glass capillaries tube (i.d. 84 µm, o.d. 250 µm) and (i.d. 300 µm, o.d. 400 µm). The electrode with its protecting glass tubes was attached to a manually operated microfeed. After electrode implantation via a vertically moving stereotaxic manipulator, the microfeed was affixed to a synthetic platform chronically implanted onto the head of the animal. The miniature transmitters and steel ground electrode were removed before MRI.

Two squirrel monkeys (*Saimiri sciureus*) were anesthetized using pentobarbital and fixed with a head holder in a prone position. T1-weighted (3D FLASH, TR/TE = 22.3/10.1 ms, isotropic resolution: 330 µm) and T2-weighted 3D MRI (3D FSE, TR/TE = 3000/127.3 ms, 16 echos, inter-echo-spacing = 16.1 ms, isotropic resolution: 469 µm) was carried out at 2.35 T (Bruker Biospin) using a 10 cm Helmholtz coil. Examinations were performed both before and after implantation. BOLD sensitive MRI sequences were not employed, because it was not intended to combine neurophysiological investigations with fMRI [4]. Histological evaluation of brain tissue was undertaken in two common marmoset monkeys (*Callithrix jacchus*) to keep the squirrel monkeys for our neuroethological project. An identical electrode (n=8) implantation procedure and MRI protocol was applied under ketamine-xylazine anesthesia. After MRI, eight additional electrodes (controls) were inserted into the brain. The animals were perfused with 10% buffered formaldehyde solution and coronal brain sections, stained with hematoxylin-eosin, were evaluated by light microscopy.

Results

Figure 1 demonstrates that platform, microfeed, glass capillaries, and microelectrodes are well delineated without generating distortions in respective MR images. While T2-weighted images reveal better grey/white matter contrast, T1-weighted images more clearly differentiate between the glass tubes and the microelectrode. Therefore, T1-weighted images (see Figure 2) are particularly useful for monitoring the positions of the electrode tip at different stages during electrophysiological exploration of the same animal. Histological examinations without pathological findings in the brain of common marmosets strongly suggest that the brain tissue surrounding the tip of the microelectrode is not harmed by the MRI investigation.

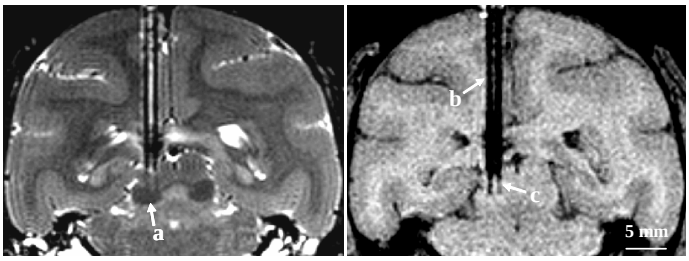

Figure 1: T2-weighted (left) and T1-weighted image (right) of a squirrel monkey brain with two implanted electrodes. (a) inferior colliculus, (b) glass tubes with metal core, (c) advanced microelectrode.

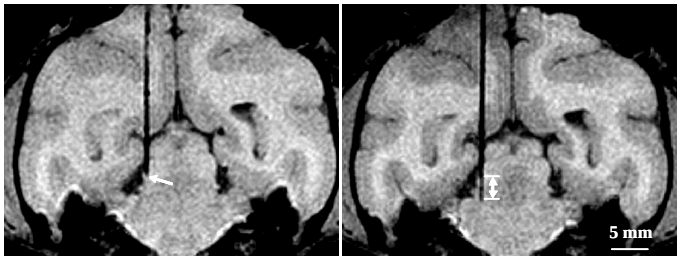

Figure 2: T1-weighted images of a squirrel monkey brain showing two different positions of the electrode tip: 0.4 mm (left) and 2.9 mm (right) distance to the glass tube end.

Conclusions

All components of the assembly are MRI-compatible. T1-weighted 3D MRI allows for the verification of the position of microelectrodes. The absence of histological lesion around the microelectrode enables follow-up MRI studies during the course of neuroethological experiments.

[1] Asahi T, Tamura R, Eifuku S, Hayashi N, Endo S, Nishijo H, Ono T. A method for accurate determination of stereotaxic coordinates in single-unit recording studies in monkeys by high-resolution three-dimensional magnetic resonance imaging. Neurosci Res 2003; 47:255-260.

[2] Scherberger H, Fineman I, Musallam S, Dubowitz DJ, Bernheim KA, Pesaran B, Corneil BD, Gilliken B, Andersen RA. Magnetic resonance image-guided implantation of chronic recording electrodes in the macaque intraparietal sulcus. J Neurosci Meth 2003; 130:1-8.

[3] Tammer R, Ehrenreich L, Jürgens U. Telemetrically recorded neuronal activity in the inferior colliculus and bordering tegmentum during vocal communication in squirrel monkeys (*Saimiri sciureus*). Behav Brain Res 2004; 151: 331-336.

[4] Logothetis NK, Pauls J, Augath M, Trinath T, Oeltermann A. Neurophysiological investigation of the basis of the fMRI signal. Nature 2001; 412:150-157.