Functional neuronavigation using an interventional magnetic resonance imaging (iMRI) system

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Introduction
Biopsy and resection of brain tumors in eloquent areas remain challenging tasks because of the potential risk of postoperative neurological deficits and, consequently, a severe deterioration of life quality. Biopsy and resection of brain tumors in eloquent areas remain challenging tasks because of the potential risk of postoperative neurological deficits and, consequently, a severe deterioration of life quality. Currently, many intraoperative identifications of eloquent brain areas are still based on anatomical landmarks. It is well known, however, that there is no exact correspondence between functional areas and anatomical structures. In addition, these structures can be altered by the tumor and the perifocal edema. Functional magnetic resonance imaging (fMRI) is widely accepted as a reliable method for the non-invasive localization of eloquent areas. For interventional neurological procedures with an open MR scanner, it is, therefore, highly desirable for the neurosurgeon to map preoperative fMRI results onto the oblique anatomical iMRI planes determined by a localization device. An excellent correlation between fMRI maps and invasive intraoperative electrophysiological stimulation has been shown in a few studies involving the sensorimotor cortex [1,2,3]. In the present work, an existing interventional navigation system (LOCALITE) has been extended by an iMRI module to allow the integration of preoperative functional MR data into intraoperatively acquired 3D-MR data sets. The aim of our study was to evaluate the feasibility of this promising combination as a tool for improved neurosurgical navigation.

Methods
Out of a patient group selected for open MR-guided resection, eight patients with cerebral lesions close to the central sulcus were enrolled in this preliminary study. Out of a patient group selected for open MR-guided resection, eight patients with cerebral lesions close to the central sulcus were enrolled in this preliminary study. The preoperative functional data were acquired on a 1.5 T scanner (Magnetom Vision, Siemens, Erlangen, Germany) using EPI (TR 4 sec, TE 66 ms, 128 x 128, FOV 23 cm, 60 NEX). The sensorimotor cortex activation was achieved with a finger tapping paradigm. For iMRI post processing, the Siemens software mripp was used. Anatomical reference images were recorded with T1 weighting (TR 448 ms, TE 15 ms). These images are inherently registered with the EPI data set and serve as a basis for fMRI–iMRI mapping. Intraoperative imaging was performed on an open MRI scanner (Signa SP, 0.5 T, GE, Milwaukee, WI) equipped with a hand-held localization device (Flashpoint, IGT, Boulder, CO). Conventional neuronavigation with this system is based on T1-weighted real time images (TR 30 ms, TE 7.5 ms, one frame every 4 sec). The certified LOCALITE Navigator (GMD, Sankt Augustin, Germany) has been introduced into this environment to improve navigation procedures with respect to speed and image quality [4]. Simulated real time navigation (3 frames per sec) is achieved by rendering high quality image planes out of intraoperatively acquired 3D data sets using a 3D (FSPGR) T1-weighted sequence (TR 13.3 ms, TE 2.7 ms/fr). The extension modules fMRI Tester and fMRI Navigator (LOCALITE GmbH, Bonn, Germany) have been designed to integrate functional information into this enhanced neuronavigation.

Integration of the fMRI data into the intraoperative environment is currently based on the identification of corresponding fiducial markers or anatomical landmarks in the preoperative (1.5 T) anatomical reference images and in the intraoperative images, respectively.

Results
A screenshot of the LOCALITE fMRI Tester is displayed in Fig A and the corresponding anatomical T1-weighted reference images (bottom part) can be interactively manipulated in different planes. Although inherently registered, this comparison allows the evaluation whether the patient has moved between both data acquisitions. In this case, no significant shifting could be observed and the T1-weighted images could be used as a reference set for functional navigation. In the fMRI Navigator environment, the T1 data set of the functional investigation was registered (here, using three marker pairs) and superimposed on the previously acquired 3D iMRI data set (Fig. 2). The quality of the resulting overlay can be evaluated within an arbitrary slice by moving a lens across the screen. For quality control, the distances of the marker positions in the common (registered) coordinate frame and their mean value (here, 0.9 mm) will be given as guiding values. Overlays of preoperative functional (BOLD) MR data onto intraoperative 3D anatomical MR images are the basis for the determination of distances between tumor and eloquent areas (static mode, Fig. 3) and for functional neurosurgical navigation (real time mode, Fig. 4).

Discussion
With the use of functional MR data sets and their co-registration with iMRI data sets, the projection of functional areas onto anatomical information was made possible. With the use of functional MR data sets and their co-registration with iMRI data sets, the projection of functional areas onto anatomical information was made possible. By integrating these procedures into a surgical navigation system, the neurosurgeon can localize eloquent brain areas prior to tumor resection and, therefore, before brain shift occurs. The relevant distances between tumor and eloquent brain areas can be determined in arbitrary, also oblique, views. We expect that the current implementation of a functional neuronavigation system represents the starting point for future developments and clinical investigations to improve surgical benefit and postoperative outcome.

References