Intraoperative high-field MRI supported by neuronavigation: first clinical experience

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Synopsis
A high-field MR scanner was adapted to the needs of an operating room environment. Surgery at the 5 Gauss perimeter was realized by a rotating operating table, which serves as MR tray. Furthermore, a ceiling-mounted neuronavigation system was installed in the radiofrequency-shielded operation room. Functional neuronavigation for preservation of eloquent brain areas was added by integration of functional data from fMRI and magnetoencephalography. Preliminary experience gained with the first 74 patients is summarized and compared to the experience in the application of low-field intraoperative MRI, performed in 330 patients.

Introduction
The aim was to establish a new setup for intraoperative imaging, combining the benefits of high-field magnetic resonance imaging with microscope-based neuronavigation, providing anatomical and functional guidance. Furthermore, intraoperative application of MRI either using a low- or a high-field system in respect to setup, workflow, and first clinical results was compared.

Methods
A rotating operating table (Trumpf, Saalfeld, Germany) was adapted to a 1.5 T MR scanner (Magnetom Sonata, Siemens Medical Solutions, Erlangen, Germany), placed in a radiofrequency-shielded operating theater. Active magnetic shielding of the scanner allows the combination of surgery in the fringe field with high-field MRI. The navigation microscope (NC4-Multivision, Zeiss, Oberkochen, Germany) placed in the 5 Gauss zone in combination with a ceiling mounted navigation system (VectorVisionSky, BrainLab, Heimstetten, Germany) enables integrated microscope-based neuronavigation. Functional data from fMRI or magnetoencephalography are registered to the 3-D navigational dataset (1.0 mm isotropic 3-D MPRAGE dataset (magnetization prepared rapid acquisition gradient echo sequence; FOV, 250 mm; TR, 2020 ms; TE, 4.38 ms) [1, 2].

Results
74 patients, mainly gliomas and pituitary adenomas, were investigated with intraoperative high-field MRI; including 34 transphenoidal approaches, 34 craniotomies, and 6 burr hole procedures. In 20% of all patients intraoperative MRI resulted in a repeated inspection of the surgical field with an extension of the resection. In 30 patients microscope-based navigation was used, in 11 functional data were integrated. Navigational accuracy was not impeded by the magnetic fringe field. Imaging quality was not disturbed by the operating environment; there was hardly a difference in imaging quality between pre- and intraoperative scans. Intraoperative workflow with intraoperative patient transport for imaging was straightforward; imaging could start in less than 2 minutes after sterile covering of the surgical site. We did not encounter any untoward events due to the high magnetic field. Intraoperative low-field MR imaging using a 0.2 T Magnetom Open scanner was applied in 330 patients [3, 4, 5]. In both systems surgery was performed at the 5 Gauss line, so standard neurosurgical micro-instruments could be applied. The rotating OR-table adapted to the high-field system improved intraoperative workflow. Intraoperative patient transport was less time consuming (2 min vs. 10 min). Reduced scanning time (factor 2-3) allowed the application of further sequences in the same time-frame with the 1.5 T system. Image resolution of the 1.5 T intraoperative images was clearly superior, e.g. the high-field system allowed the clear identification of the pituitary stalk in the intraoperative post-resection pituitary cases, as well as a good delineation of the cortical border in gliomas, which was rarely possible with the 0.2 T scanner. High-field imaging did not result in additional artifacts.

Conclusion
Standard high-field MR scanners can be successfully adapted to an operating environment including integrated neuronavigational support. Their intraoperative application offers increased image quality and a broad spectrum of different imaging modalities, compared to previous low-field systems. Active magnetic shielding of the high-field scanner allows surgery in the fringe field, as in the setup of the 0.2 T system. Intraoperative image quality of the 1.5 T system outranges that of the low-field system, as anticipated from standard examination conditions. The broader sequence spectrum offers new avenues in intraoperative imaging. Beyond intraoperative anatomical imaging evaluating the extent of tumor removal, investigations of function, spectroscopy, and diffusion become possible.

References