Where will the Future Take Us?

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Interventional and intraoperative MRI (iMRI) has been introduced more than a decade ago. Since then it has been generally accepted as a valuable image-guidance tool but it is still immature, its clinical indications are not well defined and its potential impact on everyday practice is not fully recognized yet. The main reason for the relatively slow proliferation of this technology is not necessarily the high cost of MRI systems but the lack of clear definition of the various types of clinical procedures and the iMRI systems. Neither the configuration nor the field strength of the MRIs or their integration with the current conventional operating room environment and with multiple therapy devices has been determined yet.

In order to realize the potential benefits of intraoperative MRI one has to understand all the possible implication of this new approach. In a fundamental way, visualization beyond the exposed surface is an unrealized dream of surgeons, and iMRI has expanded the limits of the surgeon's view of the operational field from 2D to 3D. This aspect of MRI guidance can be used for minimally invasive endoscopic procedures. iMRI also augments the surgeon's eye by a more effective tissue definition than direct visual examination. However, the main reason for the intraoperative use of MRI has been to correct for deformations and to avoid incorrect localization and targeting. This major advantage in surgical guidance will be utilized beyond neurosurgery.

Some of the MRI measurable physical or physiological parameters (temperature, diffusion, perfusion and flow) are especially useful for intraprocedural monitoring of interventions like thermal ablations or endovascular procedures. These quantitative parameters should be obtained using dynamic imaging sequences otherwise they cannot be used for the closed-loop control of energy depositions or the detection of functional responses to vascular insults. This dynamic imaging requirement imposes serious requirements for both MRI hardware and software. The closed loop control also mandates the full integration of therapy devices with MR imaging. That is the reason that the future development of intraoperative MRI requires advances in imaging techniques and a series of further integration steps. The hardware and software components and the imaging features of MRI have to be integrated into the operating room environment and the various surgical instruments, tools and therapy devices have to be strongly coupled with the software and hardware components of the imaging systems. In the future intraoperative MRI has to be a fully integrated module of a complex image based therapy delivery system. iMRI, however, not only represents a technical challenge but also a transformation from conventional hand-eye-coordination to interactive, navigational operations.

Current clinical applications are successfully incorporating real time and/or continuously updated image-based information for direct intraoperative visualization. In addition to using traditional image-guidance intraoperatively, we also foresee optimized use of molecular marker technology, as well as the integration of the next generation of surgical and therapy devices (including image-guided robotic systems). Although we expect the primary clinical thrusts of MRI-guided therapy to remain in neurosurgery, we also anticipate increased use of MRI-guided, focal thermal ablative methods (e.g., laser, radiofrequency, cryoablation and high intensity focused ultrasound). The integration of FUS with Magnetic Resonance Imaging (MRI), represents a major step towards a non-invasive image-guided therapy substitute that can replace most of the existing tumor surgery methods. Although MRgFUS technology is still in its infancy, this revolutionary imaging technology has already been established and it is undeniably the most promising iMRI method in the field of image-guided therapy today. It is applicable not only in the thermal coagulative treatment of tumors but also in several other medical situations for which invasive surgery or radiation may not be an effective treatment options. With additional research, we will develop MRgFUS applications for CNS and vascular diseases, targeted drug delivery, gene therapy, and more.