Intraoperative MRI

- The intraoperative MRI surgical suite is a full-service operating room that allows MR imaging during surgery without moving the patient from the surgical table.
- Intraoperative MRI allows visualization of lesions, which may shift after a craniotomy is performed and can allow a more extensive resection.
- Intraoperative MRI may be used to detect complications, such as bleeding, allowing treatment before the patient leaves the operating room.
- Neurosurgical indications for intraoperative MRI include resection of tumors, vascular malformations, and epileptic foci.

Figure 1. The MGH intraoperative MRI suite. Photo courtesy of Anton Grassl/Esto

Imaging is essential for planning many neurosurgical procedures, particularly resection of brain lesions such as tumors. Anatomical imaging shows the location and extent of lesions; diffusion imaging can show the positions of major neural tracts; and functional imaging shows the location of eloquent cortex such as that necessary for language or movement. However, the brain lesion may be difficult to distinguish visually from adjacent normal brain; therefore, anatomical landmarks are typically employed in guiding resections. These landmarks are frequently deformed after a craniotomy because the brain typically relaxes and changes shape, especially in cases in which there is a large tumor pressing on adjacent structures. The average amount of displacement has been reported to be 1 cm. Although neurosurgeons generally use anatomical features such as sulci to correct for brain...
Figure 2. (A) A pre-operative axial T2 FLAIR MR image shows a large, T2 hyperintense mass lesion infiltrating the left temporal lobe and insula (subsequently determined to be anaplastic oligoastrocytoma). (B) An intra-operative image shows marked deformations of the brain due to craniectomy and extensive resection of the T2 hyperintense lesion. Image guidance based on the pre-operative scan would have no longer been reliable because anatomic landmarks were distorted. Based upon the intra-operative imaging, the surgeon was able to identify additional areas that could be safely resected, as well as areas that were too close to vital brain structures to be safely removed.

shift, it can be difficult to judge the extent of a lesion or the position of eloquent cortex. Intraoperative MRI offers the ability to provide visualization of any remaining lesion before surgery is completed, which enables more accurate and complete resections. Intraoperative MRI can also be used to check for complications such as bleeding, which can then be treated without delay. If there are any concerns about infarction or an ischemic event, diffusion-weighted imaging can be performed promptly to evaluate the extent of tissue damage.

Clinical Indications for Intraoperative MRI
Clinical indications for the use of intraoperative MRI in neurosurgery include resection of tumors (both primary and metastatic), epileptic foci, and neurovascular malformations such as cavernous malformations, arteriovenous malformations, and arteriovenous fistulae.

The most-studied use of intraoperative MRI has been for surgical removal of gliomas and glioblastomas, which are malignant intrinsic brain tumors that are best treated by the most complete resection possible. More extensive removal of these tumors, especially non-enhancing tumors, is correlated with longer survival, and several studies have shown that intraoperative MRI has facilitated more complete resections. For example, in one study of 135 patients, intraoperative MRI detected residual tumor in 88 patients; 19 of these received more extensive resection and for nine of these patients, complete resection was achieved. For the remaining patients, further resection was not possible without damaging eloquent areas or white matter tracts.

Another common use for intraoperative MRI is during surgery for pituitary adenomas. These are usually resected via a trans-sphenoidal approach and, in the past, MRI was used in the days following surgery to check for complete removal. Any remaining tumor was treated with radiation. Now intraoperative MRI can be used to confirm removal and, if there is any residual tumor, surgery can resume.
Neurovascular malformations, especially cavernous malformations, are also being treated in the intraoperative MRI suite. Imaging datasets are used to evaluate the extent of the lesion and plan the surgical access route. Intraoperative MRI can be used to confirm complete removal of the lesion, although it is primarily used to evaluate intraoperative complications.

**Interoperative MRI at the MGH**

To address the safety issues of working in a high-magnetic field, all surgeons, anesthesiologists, nurses, surgical technologists, MRI technologists, and support staff who work in the intraoperative MRI suite have completed specialized training. In addition, each surgery in the intraoperative MRI suite must follow a series of checklists to ensure that appropriate policies and procedures are being followed. While the checklists increase case duration, they are an important mechanism to ensure MRI safety in the suite. The intraoperative MRI suite has been in operation since July 2012.

In most intraoperative MRI cases, high-resolution anatomical and functional imaging is carried out in the days leading up to surgery at a site other than the intraoperative MRI suite. In cases in which stereotactic guidance is used during surgery, these scans can be performed in the intraoperative MRI suite. Imaging sequences include T2, T2 FLAIR, and T1, with and without contrast material to determine the size, position, and enhancing characteristics of the tumor. Diffusion-weighted imaging is used to detect diffusion anisotropy and create tractography images that show the major white matter tracts. fMRI is used to detect regions of eloquent brain. MR spectroscopy can be used to show regions of metabolite abnormalities, such as decreased levels of n-acetyl aspartate and increased levels of choline. Reconstruction of the imaging data is used to create 3D images.

Intraoperative MRI is performed in a new surgical suite in the Lunder Building. The suite features a 3T MRI scanner, capable of a full range of imaging protocols, mounted on a ceiling track, which allows it to be moved from a magnetically shielded enclosure into either one of two adjacent operating rooms. This arrangement allows scheduling of more than one intraoperative MRI case per day. The operating room equipment, including the surgical table, is designed to be compatible with the strong magnetic field associated with MRI. However, because the scanner is enclosed in a shielded enclosure during surgery, it is possible to use ferromagnetic surgical tools. These must be removed from the magnetic field and counted before imaging.

Intraoperative MRI is typically performed after the neurosurgeon feels that he has removed as much of the diseased tissue as possible without causing neurological deficits. When it is safe to do so, the scanner is moved out of its enclosure into the operating room towards the patient who remains on the surgical table. A neuroradiologist selects the imaging protocols, based on the presurgical imaging findings. If further surgery is necessary, the MRI scanner is moved back into its enclosure before surgery is resumed.

There is little information at present on the cost-effectiveness of intraoperative MRI. There is, however, one report that indicated the length of stay following intraoperative MRI was 55% shorter for first-time resections and 31% shorter for repeat resections compared to conventional surgical procedures. In addition, the number of repeat resections was reduced in patients who received intraoperative MRI.

**Scheduling**

The intraoperative MRI suite can accommodate two cases per day, one in each of the two operating rooms that adjoin the intraoperative MRI scanner.

**Further Information**

For more information about intraoperative MRI imaging, please contact Mykol Larvie, MD, PhD, Neuroradiology Division, Mass General Imaging, Massachusetts General Hospital, 617-726-8320.

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References


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