Intraoperative high field magnetic resonance imaging in neurosurgery: Our initial experience with the brain suite

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We present our initial experience with the high field (1.5T) intra-operative magnetic resonance imaging, the operating room set-up, our initial cases, the difficulties we faced and how this tool affected a change in the surgical strategy intra-operatively and finally our results. 11 patients were operated on from June 1st to August 1st 2006 of which there were astrocytomas (7), pituitary adenoma (1), craniopharyngioma (1) and meningiomas (2) Localization and lesion targeting were accurate, intra-operative imaging helped to assess the resection volumes, enable corrections for brain shift, perform further tumor resection at the same sitting and help preserve eloquent cortical areas. Gliomas formed 63.6% of the tumors operated on and in 71.4% of these, our surgical strategy changed intra-operatively. Meningiomas formed 9.1% of the tumors operated and image guidance enabled a minimally invasive approach, although no change in our surgical plan was required. One pituitary adenoma and a craniopharyngioma were also operated on with good outcome.

Key words: Intra-operative high-field magnetic resonance imaging, iMRI, neuronavigation

Introduction

Conventional image-guided systems would work under the assumption that the brain is rigid, and there will be no shift or deformation taking place during surgery. However, several factors will bring about changes causing deformation and brain shift, namely cerebral edema, drainage of cerebrospinal fluid via cisterns or ventriculostomy, diuretics used in surgery, the craniotomy itself, positioning, gravity and finally tumor resection. Certain investigators studies on this phenomenon have shown that shifts of up to 20 mm are possible.[3] The intra-operative ultrasound and CT were incorporated, but had their limitations.[4,5] The use of the first intra-operative magnetic resonance imaging (MRI) started in 1995[7] with the so-called ‘double doughnut’ design, which was dedicated to use in the operating room. The introduction and use a high field (1.5T) intra-operative MRI was subsequent to the development of active shielding of the superconducting magnets, thus allowing surgery to be performed in the fringe fields. High quality MRI's both anatomical and functional is possible with minimal shifting of the patient.[10,11]

Materials and Methods

Eleven patients underwent surgery, seven were histopathologically proven gliomas of varying grades, two were meningiomas, one pituitary adenoma, and one was a craniopharyngioma. In three patients, the tumor was located adjacent to the speech area and one was adjacent to the right motor cortex. The other three patients had low-grade tumors away from the surface parenchyma. A detailed informed written consent for all patients being operated in the OR with the intra-operative MRI was done.

The entire operating room (OR) had to be radiofrequency (RF)-shielded and changes were required in the operating room; no metal instrument could be left on the operating table during the imaging. The scanner is a Siemens (Siemens AG Medical Solutions, Erlangen, Germany) with a superconductive active shielded magnet with a length of 160 cm and an inner bore diameter of 60 cm equipped with a gradient system with a field strength of up to 40 mT/m (effective 69 nT/m) and a slew rate of up to 200 T/m/s (346 T/m/s effectively). The tubing’s, intravenous and arterial lines are much longer (6 m) than those used in a conventional OR, allowing access to the MR gantry. Three infusion pumps are shielded in an MR compatible carrier (MR caddy).

The Carl Zeiss Opmi Pentero Multivision microscope placed outside the 5G line is used with the ceiling-mounted navigating system (Vector Vision Sky-BrainLab) enabling integration of the microscopic images...
with navigation. The intra-operative MRI parameters and the sequences are an initial MRI that prior to surgery is a non-contrast sequence and the protocol includes the localizer first and then the TREGS. We then perform a 3D-T1 SPGR sequence with a TR-2200, TE-3.9; continuous slices 1.5 mm thick with an FOV of 350. This is the sequence, which is used in navigation. In addition to this, we perform a T2 axial, sagittal, and coronal sequence. The parameters here are a TR-5460, TE-100, with 5 mm thick slices and the same FOV. The same sets of sequences are performed at any point of time during surgery and also at the end of surgery. An additional sequence of images which we have been performing in the intra-operative and the post-operative MRI’s is the diffusion weighted images (DWI) and (GRE).

The patient’s head is fixed onto an MRI compatible 4-point head fixation device in the required operating position this is done following induction and anesthesia. There are two head coils to perform the MRI, one of these is kept sterilized by using formalin tablets. This coil is used for imaging during surgery. Once the patient’s head has been fixed in the surgical position the first MRI is done, and the patient is registered in the navigation system, the skull fixation pins are used as landmarks in the registration process. The patient is then rotated outside the 5G line, the tracking probe is fixed on the head fixation device. The images of the preoperative surgical plan can be either automatically or manually fused with the image data from the first intra-operative MRI. The surgeon checks the accuracy using a spy-glass view provided by the software and if a good match is found, the fused images are accepted. The navigation system uses optical digitizers emitting infra-red light, from light emitting diodes (LED’s) and spheres reflecting this light used to track the position during surgery. Any instrument used with these spheres, in the surgical space can be tracked by the navigation system. The surgical area is prepared and then covered with sterile drapes, a sterile tracking probe is fixed to the head fixation device. The images of the preoperative surgical plan can be either automatically or manually fused with the image data from the first intra-operative MRI. The surgeon checks the accuracy using a spy-glass view provided by the software and if a good match is found, the fused images are accepted. The navigation system uses optical digitizers emitting infra-red light, from light emitting diodes (LED’s) and spheres reflecting this light used to track the position during surgery. The advantage of a 1.5T MRI would be shorter image acquisition times, ability to perform advanced MR sequences and use it for research in the study of tumors like gliomas. Taking all these factors it was decided to use the high-field (1.5T) MR system.

The learning and adjustment period for this new surgical environment was not long. The principles of frameless navigation remain the same, although the operating environment changes. Initially the period of induction for anesthesia took some time, the use of shielded infusion pumps and monitoring the patient from outside the operating room had to be optimally done. The next step, which involved positioning the patient, also took some time, as the area appeared to be restrictive. The nursing staff and technicians had to be trained on the initial equipment being used. The next step was the intra-operative high field MRI in neurosurgery to maximize the degree of resection.

The intra-operative MRI has been used on seven patients with gliomas [Table 1]. There were three patients operated via the trans-nasal route, 1 turned out to be a meningioma as discussed earlier, the other was a craniopharyngioma, and the third pituitary apoplexy. The craniopharyngioma was cystic and completely decompressed. The pituitary was easy to excise, as it was soft, easily resectable. There was tumor enhancement over the carotid on one side. Follow-up and radiosurgery were planned in this case.

**Discussion**

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**Surgery for gliomas**

Intra-operative MRI has been used on seven patients with gliomas [Table 1]. Three patients had tumour adjacent to the speech areas, of these two had been operated earlier using an awake craniotomy to preserve function. Their speech areas were mapped out a day prior to surgery and these functional images were integrated with the initial MRI where the planning was done. The Opmi Pentero operating microscope is compatible with 3-D navigation and image injection enables the surgeon to demarcate tumour from adjacent normal parenchyma.

Without the help of image injection and navigation it is very difficult to delineate these eloquent areas from large areas of infiltrating tumor. Using navigation the area which is to be resected is delineated, keeping away from the eloquent cortex. This enables resection of the tumour within the defined limits. In cases where tumor resection is partial further surgery is performed after updating the MR images and on intended completion of surgery a final MR is performed followed by closure.

There was one patient in which the tumor was adjacent to the motor cortex, a functional MRI was done to map these areas out prior to surgery and planning and surgery similarly performed. In the remaining three patients, imaging and navigation were used to localize as well as maximize the degree of resection.

**Surgery for meningioma**

Two patients were operated with a histopathological diagnosis of meningioma. In one, the tumor was a convexity meningioma. This was our first case and we decided to use it here, so that the team could get used to the setup. The size of the flap was minimized and complete excision was also confirmed!! The other patient had a sella-suprasellar lesion and was approached trans-nasally.

**Surgery for sella-suprasellar lesions**

There were three patients operated via the trans-nasal route, 1 turned out to be a meningioma as discussed earlier, the other was a craniopharyngioma, and the third pituitary apoplexy. The craniopharyngioma was cystic and completely decompressed. The pituitary was easy to excise, as it was soft, easily resectable. There was tumor enhancement over the carotid on one side. Follow-up and radiosurgery were planned in this case.

**Results**

Intra-operative MRI has been used on seven patients with gliomas [Table 1]. Three patients had tumour adjacent to the speech areas, of these two had been operated earlier using an awake craniotomy to preserve function. Their speech areas were mapped out a day prior to surgery and these functional images were integrated with the initial MRI where the planning was done. The Opmi Pentero operating microscope is compatible with 3-D navigation and image injection enables the surgeon to demarcate tumour from adjacent normal parenchyma.
operative MRI, which when we started off in case 1 took about ½ an hour, but now is done in 3–8 minutes. The initial time of 1 to 1 and ½ hours was because fixed protocols, trials, and retrials of image sequences had to be developed for the tumors and gradually became streamlined and fixed. The 3–8 minutes sequences refer to MRI’s done subsequent to the start of surgery and before closure. Here a short T2WI of 45 seconds and a long T1WI sequence of 5–7 minutes have been found to be sufficient. There are cases where more sequences are required and could take a much longer duration, but we have seen that the information we gather from these suffices in most cases. Injecting contrast and image sequences following this also take a longer duration. All the drapes were disposables and the surgical procedure, did not vary from that of a usual craniotomy. The principles of navigation remain the same, with minimal time taken for registration of the patient. The break during surgery was something new to accommodate to, which occurred while performing the intra-operative MRI. Each process has now become faster and smoother.

The disadvantages are that the integrated head fixation device cum MRI coil restricts all types of patient positioning, making it impossible for occipital and posterior fossa lesions. The table cannot be broken and varying positions like flexing the head, extension are not possible. The sitting position is also not possible. Functional MRI’s have to be done in a routine MRI, adding to the cost of the procedure and being a long duration procedure, very fatiguing to the patient.

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References


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