Intraoperative MRI and Maximizing Extent of Resection

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KEYWORDS

• Intraoperative MRI • Resection • Glioma

KEY POINTS

- Intraoperative MRI (iMRI) is a neurosurgical adjunct used to maximize the removal of glioma, the most common primary brain tumor.
- Increased extent of resection of gliomas has been shown to correlate with longer survival times.
- iMRI units are variable in design and magnet strength, which can affect patient selection and image quality.
- Multiple studies have shown that surgical resection of gliomas using iMRI results in increased extent of resection and survival time. Level II evidence supports the use of iMRI in the surgical treatment of glioma.

INTRODUCTION

Surgery for Glial Neoplasms

Surgical resection is a mainstay of a multidisciplinary approach to the management of gliomas. Numerous retrospective studies have shown that maximizing the extent of resection of gliomas improves overall survival time. Intraoperative MRI (iMRI) is a surgical adjunct designed to help the operating surgeon maximize the removal of glial tumors. During surgical resection, brain shift, surgically induced edema, and volume loss from resection can render traditional image guidance systems inadequate. These systems rely on a preoperative MRI for registration and navigation and therefore cannot compensate for the anatomic and physiologic changes that occur during surgery. iMRI incorporates an MRI scanner in the operating room, allowing the surgeon to obtain an MRI during the course of surgery, thus providing "real-time" feedback. iMRI can be used to assess the extent of tumor resection, assess changes in neuroanatomic structures, and incorporate changes in functional cortical and subcortical brain into the stereotactic navigation system. Residual tumor can then be resected while the patient is still in the operating room with an exposed craniotomy. The nature of a glial neoplasm influences how the operating neurosurgeon uses the iMRI. In this article, iMRI in the context of glioma resection is reviewed.

Radiographic Qualities of Glial Tumors

High-grade glial neoplasms, such as glioblastoma (World Health Organization [WHO] grade 4 brain tumors), generally demonstrate extensive enhancement on postcontrast T1-weighted MRIs (Fig. 1). Low-grade glial neoplasms (WHO grade 2 brain tumors) typically do not demonstrate significant enhancement but do display hyperintensity on T2-weighted MRI or fluid-attenuated inversion recovery (FLAIR) sequences (Fig. 2). These differences in imaging characteristics must be taken into account during surgery in the iMRI operating environment. In this article, these tumors will be dichotomized into low-grade (non–contrast enhancing) and high-grade (contrast enhancing) gliomas. Low-grade gliomas (LGGs) are WHO grade 2 tumors, including oligodendroglioma and

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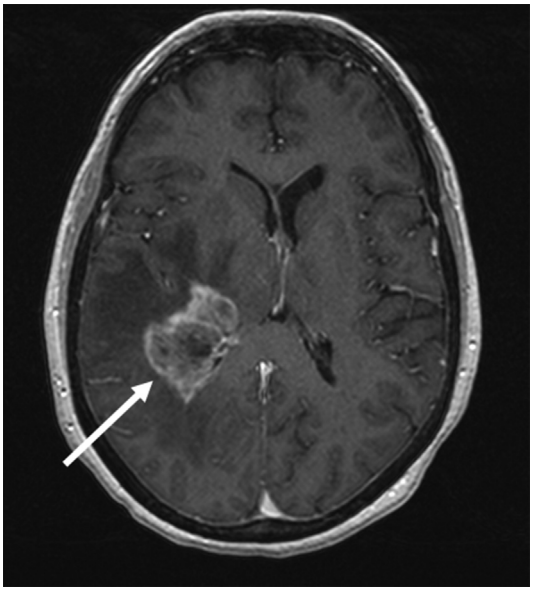

Fig. 1. Example of high-grade glioma (glioblastoma) demonstrating avid contrast enhancement on T1-weighted MRI sequence. The arrow indicates the tumor in the posterior right temporal lobe.

astrocytoma. High-grade gliomas are WHO grade 3 and 4 tumors, including anaplastic oligodendroglioma, anaplastic astrocytoma, and glioblastoma.

EXTENT OF RESECTION AND OUTCOME

Several recent studies have demonstrated an advantage for maximizing the resection of both high- and low-grade glial neoplasms. Although Level I evidence is lacking for surgical resection (compared with a nonsurgical intervention), retrospective studies examining volumetric resection have demonstrated a survival advantage for more completely resected tumors.[1–3] For glioblastoma, more complete resection of the enhancing disease is associated with a survival benefit. More recent molecular characterization of high-grade glioma has shown that isocitrate dehydrogenase 1 mutant tumors benefit from resection of the enhancing and, if present, nonenhancing component as well.[4]

Lacroix and colleagues[1] showed that survival benefit with resection of $\geq$89% of enhancing tumor. This survival benefit was most profound after resection of $\geq$98% of the enhancing disease. In another retrospective series of 500 patients with glioblastoma, resection of 78% of enhancing tumor was the threshold at which a survival advantage was achieved. This advantage increased as more tumor was removed.[3] In a retrospective review of 128 patients, residual tumor volume after resection was shown to influence survival with a statistically significant benefit in survival with less than 2 cm^3 of residual enhancing disease.[5] Taken together, these studies underscore the value of maximizing the extent of resection of glioma to improve outcomes.

LGGs have been dichotomized by risk into low- and high-grade groups using specific criteria.[6] However, extent of tumor resection was not among these characteristics. In the not-so-distant past, a conservative approach involving frequent observation had been advocated with an assumption that some low-grade tumors would

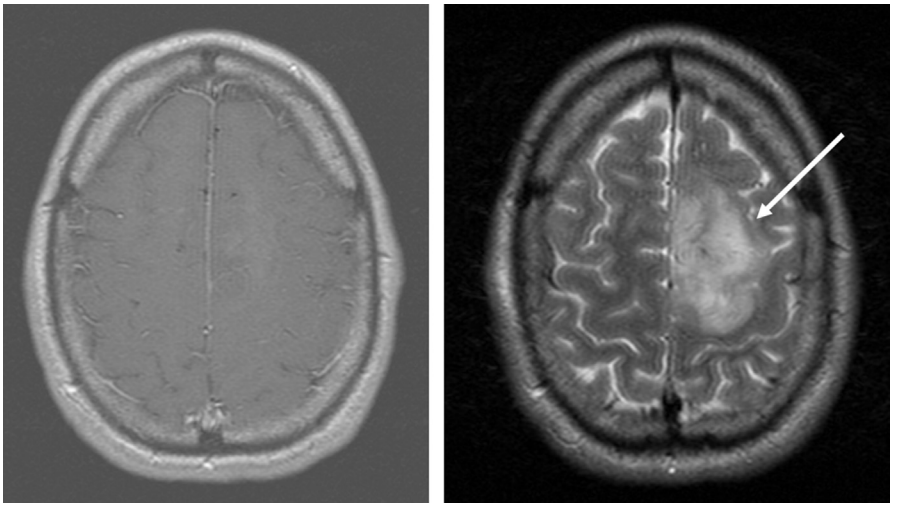

Fig. 2. Example of LGG demonstrating a lack of contrast enhancement (*left*) but significant hyperintensity on FLAIR (*right*) and T2-weighted MRI sequences. Arrow indicates tumor in the posterior left frontal lobe.