EDITORIAL

Intraoperative MRI

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WHEN we reviewed the importance of cranial imaging 8 years ago, we favored intraoperative MRI (iMRI) for cerebral gliomas.³ The trend to optimize surgical cytoreduction continues and is documented well by the Heidelberg group's paper.⁵ Historically iMRI for gliomas was pioneered by the Boston group by means of a permanent device with an 0.4-T magnet, followed some months later by the Erlangen and Heidelberg groups, using an 0.2-T magnet with a patient transportation system. It was the Heidelberg group that emphasized the influence of glioma residuals on regrowth and prognosis very early on.¹

In 2002 the Erlangen group was the first to introduce the combination of functional navigation and intraoperative high-field 1.5-T MRI in glioma surgery. Two years later they published a series of 47 gliomas, in which they documented additional resection (AR) of overlooked or microsurgically nonidentifiable tumor remnants, using iMRI.⁴ Surgical procedures were influenced by iMRI in 36.2% of the operations and surgery was continued to remove residual tumor volume. According to Nimsky et al., AR significantly reduced the percentage of final tumor volume compared with the first iMRI scan (6.9% vs 21.4%). These investigators also found that percentages of final tumor volume were significantly reduced compared with the first iMRI scan in both low-grade (10.3% vs 25.8%) and high-grade (5.4% vs 19.5%) gliomas. Furthermore, complete resection was achieved in 36.2% of all patients (57.1% of low-grade lesions and 27.3% of high-grade lesions). Finally, among the 17 patients in whom complete tumor resection was achieved, 7 complete resections (41.2%) were attributable to AR after iMRI.

The Heidelberg group changed from low- to high-field MRI in 2009, and report now on a large series of 224 patients harboring an inhomogeneous group of low- and high-grade gliomas. One of the goals in this consecutive larger series was to find out if anticipation of intraoperative findings would permit preoperative identification of ideal iMRI cases. The documented surgical results are

primarily volume oriented. The group of surgeons who operated and made the intraoperative decisions were all board-certified neurosurgeons with varying levels of experience.

The results were evaluated statistically. There was no difference between the less experienced surgeons and the other 2 groups of more experienced surgeons regarding the amount of initial resection. In 30% they were able to obtain the expected final/total glioma resection, and in 70% they had to continue surgery to obtain the optimal resection volume. In 151 of 184 cases the intended gross-total resection was achieved and the mean tumor residual volume was 0.13 cm³, which correlates to a tumor volume reduction of 99.6%. The AR total is comparable with the early Erlangen series and is surely influenced by selection of patients, the homogeneity of histological diagnosis, and the extent of image postprocessing for surgical planning.

Greater surgical experience had no significant influence on extent of tumor resection. Volumetric resection was positively influenced by glioma size, location, and the surgeon's experience. The positive predictive value of the surgeon's expectation of ARs was high, when it was definitely performed. However, a low negative predictive value of the surgeon's perception indicated in 56% of the cases that ARs were performed contrary to the surgeon's expectations. In these cases the intraoperative assessment of less experienced neurosurgeons was lower compared to those who had more experience.

The ARs per se did not lead to more neurological deficits. The overall neurological deficits are reported altogether to be comparable with those in the literature: transient in 13.4%, whereas in 9.8% minor and in 6.7% severe permanent deficits occurred. Combining minor and severe permanent deficits, 37 patients (16.5%) had permanent deficits following surgery. Presumably in the majority of these cases the tumors were in eloquent areas (n = 64). In relation to the 37 patients with permanent deficits, this would mean that approximately half of the patients who underwent operations for tumors in eloquent regions—including

9 awake surgeries—ended up with a permanent deficit. In this context it is valuable to discuss the role of functional imaging (diffusion tensor imaging–based tractography, resting state blood oxygen level–dependent functional MRI [fMRI]) and direct electrical stimulation as well as awake surgery to improve neurological outcome of surgery in patients with tumors in eloquent regions. The deficits reported may reflect the standard situation in neurosurgical departments in which open glioma surgery is performed today.

Over the years, Mitch Berger's group in San Francisco and Hughes Duffau's group in Montpellier have published frequently about the significance of “awake surgery” for intraoperative functional mapping, leading to lower rates of additional neurological deficits in senior surgeon's hands. Awake surgery is a safe option in patients with gliomas located in eloquent areas, where high-field iMRI is not available. However, awake surgery frequently includes large craniotomies and does not guarantee larger glioma resection rates, which cannot be ignored.

In contrast to the 9 differently experienced neurosurgeons in Heidelberg, experts in other centers could obtain improving functional results using iMRI, especially if combining fMRI with other functional procedures. Within our own series of more than 600 glioma surgeries performed using iMRI, in a selective series of 20 glioma patients in which senior neurosurgeons combined iMRI and direct electric stimulation, no additional neurological deficits occurred when gliomas that were directly adjacent to the corticospinal tract were removed (mean tumor volume resection 97.9%). Even neurological improvements were documented (unpublished data).

Following the prospective randomized controlled study presented by the Frankfurt group, in which low-field MRI was used to document that the use of iMRI significantly increases the extent of tumor resection,⁶ this contribution by the Heidelberg group is another study that shows this important, well-known, and accepted fact. The importance of iMRI in glioma surgery or improved prognosis is documented by increasing data from the literature, which underline that the higher the volumetric resection rate the longer the survival time. We can hopefully expect more data and arguments from the ongoing German multicenter study,² and probably from a new initiative by IMRIS users.

Two decades after the introduction of iMRI, its leading role and utility for intraoperative imaging in glioma

surgery is widely accepted. The permanent advancement of MR technologies for detection of brain function, tumor border, and brain metabolism ensures that this neurosurgical tool will remain in the forefront among other technologies (e.g., optical imaging, ultrasound, and so on) for safe radical tumor removal.

Some questions remain. Isn't it high time that the relevant industry seeks for improved ergonomic and economically responsible solutions that can be implemented in the health care systems? Do not public authorities, politicians, and insurance companies in our societies have the obligation to offer these advanced technologies for the benefit of the population?

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Disclosures

The authors report no conflict of interest.