Acta Neurochirurgica (2020) 162:3037–3041
https://doi.org/10.1007/s00701-020-04474-8

HOW I DO IT - TUMOR - GLIOMA

Intraoperative MRI guidance for right deep fronto-temporal glioma resection: how I do it

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Received: 29 January 2020 / Accepted: 24 June 2020 / Published online: 2 July 2020

Abstract

Background For glial tumor management, the extent of resection (EOR) is the key to enhance tumor control and improve patient outcomes. Intraoperative MRI (IoMRI) neuronavigated microsurgery emerged as a useful neuroimaging tool for performing optimal and safe tumor resection.

Method Here, we present the different steps of the microsurgical resection of a challenging deeply located right fronto-temporal glioma, using intraoperative MRI in an integrated IoMRI imaging platform.

Conclusion Intraoperative MRI neuronavigated microsurgery helps to enhance the tumor resection, while reducing unintended area damages. The use of IoMRI fosters a “staged volume resection,” to keep safe, taking into account the progressive intraoperative brain shift.

Keywords Brain tumor · Glioma · Microsurgical resection · Intraoperative MRI · Neuronavigation · Intraoperative imaging

Relevant surgical anatomy

We performed a right fronto-pterional approach, exposing both frontal operculum and temporal lobe. Firstly, we identify the sylvian fissure in order to avoid unintended vascular injury. Its visible part is the sylvian superficial vein, which has to be preserved. This structure could be used to check the neuronavigation accuracy.

Then, we dissected through the pars opercularis to reach the frontal component of the tumor. We avoided dissecting through the pars orbitalis to preserve as much as possible the uncinate fasciculus which connects the lateral orbito-frontal cortex to the anterior temporal lobe. Damaging this fasciculus could induce socio-cognitive impairment [10]. In the same way, we performed a small surgical corridor to reduce the lesions to the heathy right frontal lobe, as recent publications reported its role in mentalizing functions [7]. As we were working on the non-dominant side, the frontal aslant tract and the inferior fronto-occipital fasciculus were not functional boundaries. At the inner part of the fronto-basal tumor, one could see the anterior cerebral arteries. At its inferior part, there was the anterior perforated space, harboring multiple small performant arteries going to the basal ganglia. The caudate nucleus and the internal capsule were the posterior resection limits.

We carried out the temporal corticectomy through the middle temporal gyrus. Care should be given when reaching the edge of the dural tent, so as to avoid vascular injury to the choroidian artery or nerve injury, especially the III-rd and IV-th oculomotor nerves.

This article is part of the Topical Collection on *Tumor - Glioma*

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00701-020-04474-8) contains supplementary material, which is available to authorized users.

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Description of the technique

Surgery was performed under general anesthesia without intraoperative cortical or subcortical stimulation. The patient was installed in supine position, with a roll under his right shoulder. We used an MRI compatible head holder, with the head turned horizontally on the left side. Then, the navigation was calibrated using a 3D MRI performed the day before surgery with fused FLAIR and T1 after gadolinium infusion sequences. The patients underwent surgery outside the 5-Gauss line; thus, normal instruments and a surgical microscope were used for surgery.

We performed a fronto-pterional approach, with an opening of the dura mater, which allowed exposing both the frontal and temporal lobes.

Then, we used the microscope (Pentero 900 Zeiss®), synchronized with the neuronavigation. We firstly performed the frontal dissection of the tumor through a restricted frontal operculum corticectomy. We used a Spetzler-Malis® bipolar, a Brackman suction 25, and an ultrasound dissector to remove the tumor. We aimed at removing the whole T1 gadolinium–enhanced tumor until reaching the midline, without entering into the corpus callosum or the head of the caudate nucleus. We left intentionally in place a small tumor remnant at the inner part of the cavity because of the loss of accuracy of the navigation due to the brain shift (while further performing staged volume surgery). Thereafter, we continued with the temporal lobectomy through a second corticectomy below T1 gyrus, reaching the edge of the dura using gentle subarachnoid dissection. The posterior limit was defined thanks to the navigation to reach the FLAIR infiltration limit. We were conservative towards the insular region, as well as towards the internal capsule at this time. The operative tumoral pieces were sent to the histology lab.

We decided to perform an IoMRI control (1.5-T MRI, General Electric®). Before translating the patient into the MRI, we ensured the quality of hemostasis, avoiding putting patties or hemostatic agents in the cavity, in order to assess high-quality MRI images. To get the best image quality, the surgeon should rinse and fill the cavity with saline solution. If you let it dry, the presence of air will hamper image quality-inducing artifacts. A checklist was methodically filled, to ensure the absence of metallic material in the surgical site that could interfere with the magnetic field. Concerning the IoMRI sequences, a volumetric 3D FLAIR and T1 after gadolinium infusion were performed to update the neuronavigation.

After discussion with the neuroradiologist, we defined the limits of the tumor remnants, located at the inner and posterior

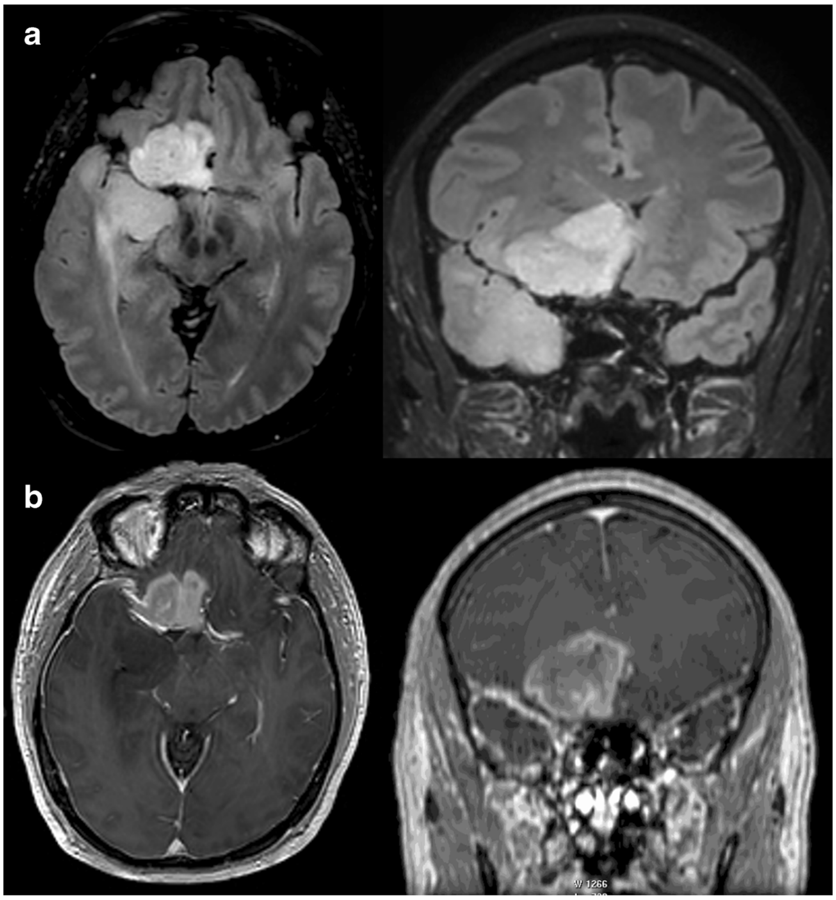

Fig. 1 Preoperative MRI related to the patient in the illustrative video. **a** FLAIR sequence. **b** T1 after gadolinium infusion

part of the frontal cavity, and at the posterior part of the temporal lobectomy.

We pursued the resection after the IoMRI control both in frontal and temporal cavities. In the frontal area, we completed the resection of the enhanced tumor near the corpus callosum and the caudate nucleus. In the temporal cavity, we enlarged the posterior resection. An infiltrative FLAIR hypersignal going to the pyramidal tract was not resected and left intentionally in place, to avoid further neurological deficits, in particular hemiplegia.

We performed a second IoMRI. No more resectable tumor was visualized.

We ended the procedure and performed the hemostasis, waterproof closing of the dura, bone flap fixation, and skin sutures. No drain was used (Figs. 1, 2, and 3).

Indications

The use of IoMRI guidance has been reported as a help to increase the extent of resection in glioma [1, 4, 9]. Its benefit for the patients was particularly reported for non-enhancing gliomas [2, 5, 6]. In this case of deep-seated, large, and heterogeneous glioma (frontal part enhancing, temporal part without contrast intake), the IoMRI guidance was most helpful.

Limitations

If this glioma was located in the dominant hemisphere, we should have performed cortical and subcortical mapping in awake condition to reduce postoperative phasic disorder, assessing the frontal aslant tract, inferior fronto-occipital fasciculus, arcuate fasciculus, and Broca's area.

The use of IoMRI prolonged the duration of intervention. In our experience, the acquisition of IoMRI, including the patient transfer inside the MRI, required a median time of 34 min (IQR, 25–42) [5]. In case of a second acquisition, it was shorter because no gadolinium injection was redone.

One could assume that IoMRI increases the risk of surgical site infection due to the patient transfer and the prolonged operation time. In practice, no additional infectious complication was reported using IoMRI [3, 5].

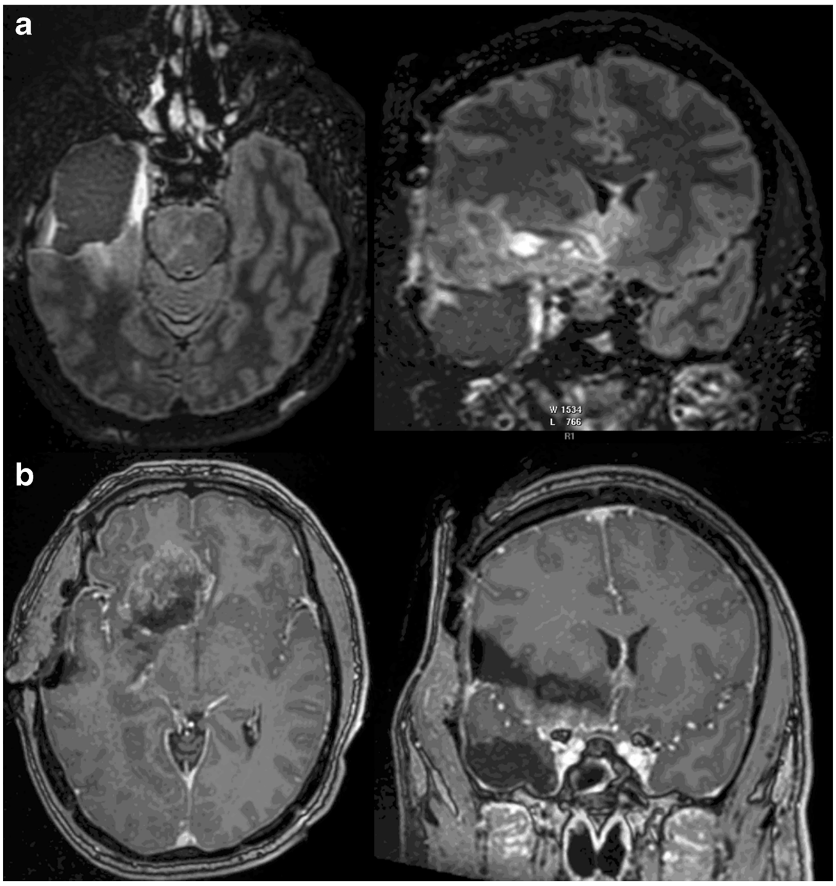

Fig. 2 Intraoperative MRI. The tumor remnant in the fronto-basal area can be delineated. **a** FLAIR sequence. **b** T1 after gadolinium infusion

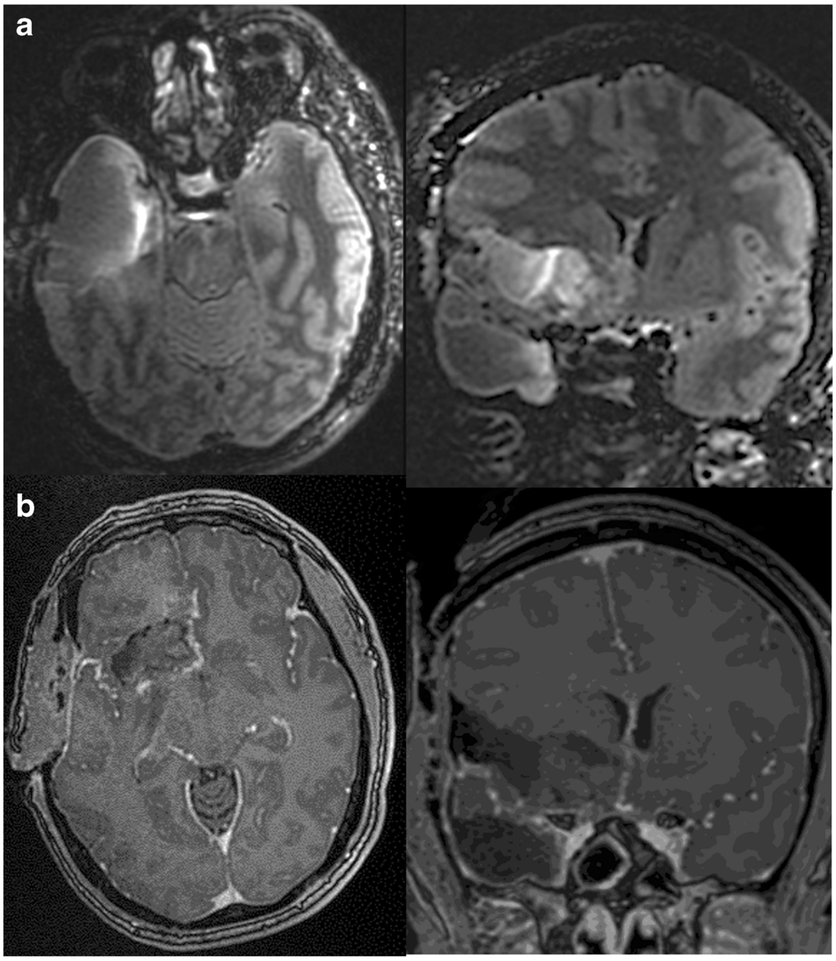

Fig. 3 Postoperative MRI related to the same patient. **a** FLAIR sequence. **b** T1 after gadolinium infusion

How to avoid complications

During the tumor resection, we avoid coagulating with bipolar to dissect the brain tissues towards the healthy parenchyma. We used a microspatula and the Brackman suction to detach the tumor bulge from its edge. The ultrasound dissector is also an option to avoid vessel injury.

As the neuronavigation was synchronized with the microscope focus, care should be given to adjust the focus so as to get the right position on the MRI. The hand pointer is an option to check the navigation accuracy on rigid surface or large vessels. In case of significant loss of accuracy, it is time to perform an IoMRI.

Before moving the patient into the MRI, a dedicated checklist was systematically filled to ensure the absence of metallic instruments in the operative field.

Specific perioperative considerations

Preoperative workup

The MRI which is used for the navigation has to be as recent as possible. In our institution, the patient underwent navigation MRI the day before surgery. We included functional, task-based speaking MRI to assess the patient lateralization. If needed, functional neuronavigation (e.g., functional MRI, diffusion tensor imaging) can be added to the anatomical navigation [8].

When installing the patient on the operative table, care should be given that the installation is compatible with the diameter of the inner IoMRI canal, using a dedicated gauging device.

Instructions for postoperative care

We currently deliver corticosteroids (1–2 mg/kg) at the end of the procedure, with progressive withdrawal.

If the patient underwent an IoMRI control with no further dissection, we consider it as his "early" postoperative control and do not ask another MRI.

All patients harboring glioma underwent close clinical and radiological follow-up.

In this case, the lesion was as a glioblastoma WHO grade IV. During early postoperative course, no additional deficit was reported. The mild left hemiparesis persisted. A concomitant radiotherapy and chemotherapy protocol was decided after collegiate discussion.

Specific information to give to the patient about surgery and potential risks

In this case of right fronto-temporal glioma, the main inherent risks are ischemic strokes beyond the surgical cavity inducing neurological disabilities such as left hemiplegia and socio-cognitive impairment.

The use of IoMRI does not understand any additional risk (infectious or hemorrhagic) in comparison with other neurosurgical techniques (standard navigation, cortico-sub-cortical stimulation) [5].

Summary of 10 key points

1. Intraoperative MRI is useful to enhance the extent of resection (EOR) for gliomas.
2. Such fronto-temporal lesion in the non-dominant hemisphere can be operated safely under general anesthesia with the help of IoMRI.
3. The preoperative MRI used for initial navigation has to be as new as possible (the day before).
4. We advocate for a step-by-step tumor dissection, called "staged volume resection."
5. Do not hesitate to let intentional remnants when you consider the navigation imprecise.
6. When the surgeon finds a lack of navigation accuracy, while considering the safe EOR accomplished, it is time to perform an IoMRI.
7. To get the finest MRI images, it is important to get an efficient hemostasis, avoiding too much patties or hemostatic agents into the cavity.
8. You can perform as many IoMRI as you need for the patient safety.
9. A volumetric assessment of the tumor resection can be performed and helps the surgeon to calculate the EOR.
10. Using IoMRI, every tumor remnant is known from the surgeon, and the former can evaluate at each time the benefit-risk equation to remove it or not.

Funding information This study was funded by Lille University hospital.

Compliance with ethical standards

Conflict of interest Dr. Tuleasca is scientific advisor for Elekta Instruments, AB, Sweden. This study did not benefit from any industrial financing. All the other authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (name of institute/committee) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The patient gave formal consent to publication of this video.

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