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Integrated functional neuronavigation-guided resection of small meningiomas of the atrium via the paramedian parieto-occipital approach

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ABSTRACT

Objective: Small meningiomas located in the atrium of the lateral ventricle remain a challenge for neurosurgeons due to the eloquent nature of the surrounding anatomy. Functional MRI (fMRI) and diffusion tensor tractography (DTT) allow for in vivo demonstrations of eloquent cortical structures and neuronal fiber tracts, respectively. Our objective is to evaluate the contribution of functional neuronavigation combined with fMRI and DTT results to surgical outcomes.
Materials and methods: we investigated 11 patients with small meningiomas located in the atrium of the lateral ventricle who underwent surgery with the aid of functional neuronavigation via the paramedian parieto-occipital approach. The patients willingly underwent assessments of neurologic deficits preoperatively and postoperatively at discharge and at three months after surgery.
Results: Gross total resection was achieved in all patients, and no residual or recurrent tumors were observed on follow-up imaging. There was no mortality. Only one patient suffered from transient postoperative aphasia (mild to moderate) that was resolved one week after surgery. No novel neurologic deficits were present in any of the other patients, and no new-onset epileptic attacks were observed.
Conclusions: With the aid of the neuronavigation that incorporates fMRI and DTT results, small meningiomas located in the atrium of the lateral ventricle can be safely resected through the paramedian parieto-occipital approach.

1. Introduction

The primary occurrence of meningiomas in the ventricular system without dural attachment is extremely rare with an incidence of 0.5–3% among all intracranial meningiomas. Eighty percent of intraventricular meningiomas occur in the lateral ventricles, and these meningiomas (approximately 90%) are particularly common in the atrium [1].

The recent increase in the widespread availability of magnetic resonance imaging (MRI) has led to the discovery of more and smaller (less than 3 cm) meningiomas in the atrium of the lateral ventricle. These tumors often cause minimal symptoms; however, due to their deep locations in the hemisphere and numerous surrounding neural fibers tracts, such as the optic radiation, pyramidal tract, and arcuate fascicle, it is difficult to locate and resected these tumors without causing complications or new neurologic deficits. Neuronavigation combined with functional MRI (fMRI) and diffusion tensor imaging (DTI) [2] results might help neurosurgeons to access these tumors while avoiding damage to the eloquent

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surrounding structures. From August of 2009 to November of 2013, we surgically treated 11 patients harboring small meningiomas located in the atrium of the lateral ventricle via the paramedian parieto-occipital approach with the aid of functional neuronavigation. The purposes of the present study were first to evaluate the role of functional neuronavigation in such surgeries and second to assess the clinical outcomes following these surgeries.

2. Materials and methods

2.1. Patient population

We retrospectively and consecutively enrolled 11 patients with small (less than 3 cm) meningiomas located in the atrium of the lateral ventricle between August 2009 and November 2013. Patients who had undergone surgeries to resect tumors prior to admission were excluded. All patients underwent surgeries aid by functional neuronavigation at our institute. The patients included 10 females and one male, and the mean age was 44.8 ± 12.9 years (range: 26–58 years). Five patients suffered from headaches, six patients suffered from dizziness, and three patients were incidentally discovered on MRI without exhibiting symptoms or signs. No epileptic attacks, visual field defects, aphasia, memory disturbances, or hemiparesis were observed. Preoperative MRI scans revealed six tumors located in the left side, five tumors located in the right side, and tumor sizes that ranged from 1.9 to 3.0 cm (mean 2.48 cm). No hydrocephalus or a trapped temporal or occipital horns were observed (detailed patient data are listed in Table 1). The local ethical committee of the hospital approved our study, and written informed consent was provided by all patients or their family members.

2.2. Preoperative image acquisition

We performed conventional MRI, DTI, and fMRI on a 1.5-T scanner (Siemens Espree, Erlangen, Germany). The parameters used were as follows: for the T1-weighted and post-contrast T1-weighted images: a magnetization-prepared rapid acquisition gradient echo (MPRAGE), sequence, echo time (TE) 3.02 ms, repetition time (TR) 1650 ms, matrix size 256×256, field of view (FOV) 250×250 mm, slice thickness 1 mm, and slab 16 cm; for the T2-weighted images: TE 93 ms, TR 5500 ms, matrix size 512×512, FOV 230×230 mm, and slice thickness 3 mm; for the T2 FLAIR images: TE 84 ms, TR 9000 ms, matrix size 256×256, FOV 230×230 mm, slice thickness 3 mm; and for the 2D TOF multi-slab sequence: TR/TE 26/7.2 ms, slice thickness 3 mm, field of view 250 mm, imaging time 4 min and 19 s). The 2D TOF multi-slab sequence was used for magnetic resonance angiography (MRA) and venography (MRV), For DTI we used a single-shot spin-echo diffusion-weighted echo planar imaging (EPI) sequence (TE 147 ms, TR 9400 ms, matrix size 128×128, FOV 251×251 mm, slice thickness 3 mm, bandwidth 1502 Hz/Px, diffusion-encoding gradients in 12 directions, b values of 0 and 1000 s/mm^2, voxel size 1.9 mm $\times$ 1.9 mm $\times$ 3 mm, 40 slices, no intersection gap, 40 continuous free-interval collection slices, five time repetitions, total scan time 10 min 22 s).fMRI data were acquired with a blood oxygenation level-dependent (BOLD) sequence in the same imaging session in which the anatomic MR imaging was performed. The paradigm for assessing motor cortex activation consisted of a 37-s ipsilateral hand motor task (cyclic finger tapping) that alternated with a 37-s contralateral motor task; this cycle was repeated three times. The paradigm used to assess language cortex activation consisted of alternating 76-s rest periods and 76-s verb generation task periods; this cycle was also repeated three times. During the application of these paradigms, an echo-planar T2-weighted imaging sequence (TE 60 ms, TR 2540 ms, FOV 192×192 mm, and slice thickness 3 mm) was applied.

2.3. Preoperative image processing

The imaging data were transferred via intranet to our neuronavigation planning station. We then used iPlan 2.6 software (BrainLAB, Feldkirchen, Germany) to perform the image processing. First, we fused the images from the different sequences. We then used the "BOLD Mapping" module to identify the hand cortex, Broca's area, and Wernicke's area. Broca's area was activated in the posterior section of the inferior frontal gyrus of the dominant hemisphere, and Wernicke's area was activated in the posterior section of the superior temporal gyrus of the dominant hemisphere. The hand cortex was activated in the pre-central gyrus. Next, we used the "Fiber Tracking" module to reconstruct the pyramidal tract, optic radiation, and arcuate fasciculus. The FA threshold was set at 0.20 to reconstruct the pyramidal tract and at 0.15 to reconstruct the arcuate fasciculus and optic radiation. We used a multi-volume of interest (VOI) algorithm for fiber tracking. We placed the VOIs on the hand cortex and the cerebral peduncle to reconstruct the pyramidal tract, on Broca's area and Wernicke's area to reconstruct the arcuate fasciculus, and on the visual cortex and lateral geniculate body to reconstruct the optic radiation. For each tumor, the fiber tract that passed through the two relevant VOIs was the final tract of interest. After selecting the appropriate fiber tract, a three = dimensional object was created by wrapping the neighboring fibers with a hull. Next, we use the "object creation" module to perform the tumor segmentation; the tumor's outermost rim was defined based on the post-contrast T1-weighted images. Finally, an optimal trajectory via the paramedian parieto-occipital approach was designed according to the 3D relationships between

Table 1
Summary of 11 patients with small size meningioma located in the atrium of the lateral ventricle.

No.	Age/sex	Side	Diameter (cm)	Symptoms	Signs	Pathology	Follow-up	Neurologic outcome complication
1	48/F	L	2.7	Headache, dizziness	None	Grande 1 fibrous	No recurrence	Aphasia that resolved at discharge
2	47/F	L	2.1	Headache	None	Grade 1	No recurrence	No deficit
3	43/F	L	2.4	Dizziness	None	Grade 1 angiomatous	No recurrence	No defict
4	51/F	L	1.9	Dizziness	None	Grade 1	No recurrence	Isolated temporal horn that cured by ventriculostomy 5 months later
5	39/F	L	2.2	None	None	Grade 1	No recurrence	No deficit
6	46/F	R	2.3	Headache	None	Grade 1 angiomatous	No recurrence	No deficit
7	58/M	R	2.9	Dizziness	None	Grade 1 transition	No recurrence	No deficit
8	26/F	R	3.0	None	None	Grade 1 transition	No recurrence	No deficit
9	47/F	L	3.0	Headache dizzness	None	Grade 1 transition	No recurrence	No deficit
10	37/F	R	2.0	Headache	None	Grade 1 fibrous	No recurrence	No deficit
11	51/F	R	2.8	Dizziness	None	Grade 1	No recurrence	No deficit