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Clinical Study

Intraoperative high-field MRI maximizes the extent of resection in intraventricular central neurocytoma surgery

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ABSTRACT

Central neurocytoma (CN) is a rare benign neuronal tumor of the ventricular system. Microsurgical resection is considered to be the mainstay of treatment for intraventricular CN, and the extent of resection is the most important prognostic factor. We describe our initial experience in the management of intraventricular CN with intraoperative MRI together with microscope-based neuronavigation. During a 5 year period between February 2009 and June 2014, 18 consecutive patients with histologically proven CN were included in this study. Gross total tumor resection was achieved in 88.9% (16/18) of patients. There were no perioperative deaths, and the overall complication rate was 61.1% (11/18). The Karnofsky Performance Status score at the last follow-up was 100 in eight (44.4%), 90 in seven (38.9%), and ⩽70 in three patients (16.7%). We conclude that intraoperative high-field MRI combined with microscope-based neuronavigation can maximize the extent of resection in intraventricular CN surgery and minimize the risks of neurological impairment.

1. Introduction

Central neurocytoma (CN) is a rare neuronal tumor of the ventricular system that is typically located in the deep midline region near the formina of Monro (particularly in the septum pellucidum or lateral ventricles). CNs were first described by Hassoun and colleagues in 1982 [1], and formally classified as a grade II nervous system tumor by the World Health Organization in 2007 [2]. The incidence of CN is estimated to be only 0.1% to 0.5% of all primary brain tumors [3–6]. Microsurgical resection is considered to be the mainstay of treatment for intraventricular CN, and the extent of resection is the most important prognostic factor [7]. Gross total resection (GTR) of CN can offer better local tumor control and longer overall survival compared with incomplete resection [8–11]. However, the majority of previous reports showed GTR was achieved in approximately one-half of patients at best [8,11,12]. In recent years, advanced intraoperative techniques, such as neuronavigation systems [13] and intraoperative ultrasound [14], have been introduced in an effort to increase extent of resection, and improve the rate of GTR to 70%.

Currently, intraoperative MRI can provide radiation-free and multi-planar intraoperative images with superior spatial resolution. It can be used as a form of immediate intraoperative quality control and to evaluate the extent of tumor removal during various brain tumor surgeries [15–18]. From February 2009, when we began to perform intraoperative high-field MRI (1.5 Tesla) scans, until June 2014, a total of 18 patients with intraventricular CN were treated at our institution. Here we describe our initial experience in the management of intraventricular CN with intraoperative MRI together with microscope-based neuronavigation.

2. Materials and methods

2.1. Subjects

This is a retrospective, single institution study. During a 5 year period between February 2009 and June 2014, 18 consecutive patients with intraventricular CN underwent surgery guided by high-field intraoperative MRI (1.5 Tesla) together with microscope-based neuronavigation. The diagnosis of CN was confirmed by immunohistochemical characteristics and electron

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microscopic findings of the surgical specimen in all cases. The medical records, radiological studies, videos of surgical procedures, and clinical follow-up data were retrospectively reviewed. Institutional Review Board approval was obtained from the Chinese PLA General Hospital for this retrospective review of the data, and informed consent papers were signed by all patients.

2.2. Intraoperative MRI technique

Intraoperative MRI was performed in a dual-room intraoperative MRI suite with a scanner with a movable 1.5 Tesla magnet (Siemens Espree, Erlangen, Germany), previously described by Chen et al [16]. Both pre and intra-operative imaging data were acquired with this scanner. The MRI acquired included a T1-weighted three-dimensional (3D) magnetization prepared rapid acquisition gradient echo sequence (echo time [TE], 3.02 ms; repetition time [TR], 2650 ms; matrix size, 256 × 256; field of view [FOV], 250 mm; slice thickness, 1 mm; slab, 16 cm), T2-weighted images (TE, 93 ms; TR, 5500 ms; matrix size, 512 × 512; FOV, 230 mm; slice thickness, 3 mm), T2 fluid-attenuated inversion recovery images (TE, 84 ms; TR, 9000 ms; matrix size, 256 × 256; FOV, 230 mm; slice thickness, 3 mm), diffusion tensor imaging sequences (TE, 147 ms; TR, 9400 ms; matrix size, 128 × 128; FOV, 250 mm; slice thickness, 3 mm; bandwidth, 1502 Hz per pixel; 12 gradient directions using b values of 0 and 1000 s/mm^2; voxel size, 1.9 × 1.9 × 3 mm), two-dimensional time-of-flight multi-slab sequence (TR, 26 ms; TE, 7.2 ms; slice thickness, 3.0 mm; FOV, 250 mm; imaging time, 4 minutes and 19 seconds), and post-contrast 3D T1-weighted images. Then, tumor segmentation and fiber tract (for example, pyramidal tract and optic radiation) reconstruction were performed by our neuronavigation software (iPlan 3.0, BrainLAB, Feldkirchen, Germany). Neuronavigation support was provided by the VectorVision Sky navigation system (BrainLAB), and the neuronavigation station was connected to a Carl Zeiss Pentero microscope (Carl Zeiss Meditec AG, Hennigsdorf, Germany). All operations were performed with the neuronavigation microscope. Details of this method are described in our previous reports [16,19,20].

Intraoperative MRI was performed when GTR or incomplete resection with inaccessible tumor remnant was thought to be achieved. If the intraoperative MRI revealed any tumor remnant that was able to be safely removed, the surgery was continued after neuronavigation was updated using the intraoperative MRI. A schematic diagram of the work flow is shown in Figure 1.

2.3. Patient evaluation

The tumor size was defined as the greatest tumor diameter on MRI, and volume calculation was performed using iPlan 3.0 software. "GTR" referred to no radiological residual tumor, "subtotal resection" referred to residual tumor ⩽20%, and "partial resection" referred to residual tumor >20%. Complications were recorded within 1 month postoperatively. The preoperative and postoperative Karnofsky Performance Status (KPS) scores were also determined for each patient at the last follow-up. Recurrence was defined as residual tumor growth or reappearance of tumor in the brain.

3. Results

3.1. Patient characteristics

The patient characteristics and treatment details are summarized in Table 1. A total of 18 patients, seven males and 11 females, were included in the study. The median age was 24.5 years and ranged from 17 to 54 years. The most common presenting symptom was headache, observed in 10 patients (55.6%), followed by nausea and vomiting in seven patients (38.9%) and hemiparesis in four patients (22.2%). The duration of symptoms varied from 3 days to 48 months (median, 2 months). The median KPS score before surgery was 90 (range, 30–100). The tumors were centered on the midline and involved both lateral ventricles in 14 patients. The other four tumors were located unilaterally. No tumor invaded the third ventricle in our series. The maximum diameters of the tumors ranged from 2.6 cm to 7.2 cm (mean, 5.5 cm). All patients had tumors with a diameter ⩾4.0 cm save two patients (Patient 11 and 17). The median volume of tumor was 48.9 mL (range, 9.3–141.8 mL).

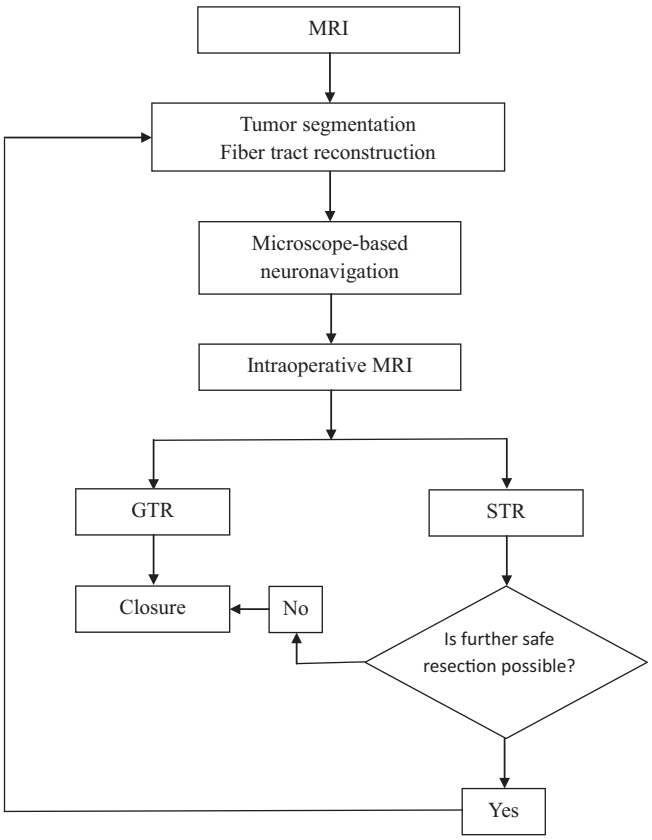

Fig. 1. A schematic diagram of the work flow for surgical removal of intraventricular central neurocytoma. GTR = gross total resection, STR = subtotal resection.

3.2. Microscope-based neuronavigation and intraoperative MRI

According to the 3D visualization of the lesion, fiber tract and bridging vein, seven patients (38.9%) were operated on transcortically, of which four were performed via the anterior approach and three via posterior approach. The other 11 surgeries (61.1%) were performed via a transcallosal approach, with all callosotomies located in the anterior and/or middle third of the corpus callosum.

GTR was detected on the first intraoperative MRI in 10 (55.6%) patients and incomplete tumor resection in eight (44.4%) patients. The percentage of residual tumor volume varied from 4% to 41%, with a median of 11%. Surgeries were terminated in 11 patients after the first intraoperative MRI with one case of incomplete resection (Patient 9) due to infiltration of critical anatomic structures. In the remaining seven subtotally resected patients, further tumor resections were continued after updating the neuronavigation. After the second intraoperative MRI, GTR was achieved in