Resection of Deep-seated Gliomas Using Neuroimaging for Stereotactic Placement of Guidance Catheters

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Abstract

A simple computed tomography (CT) or magnetic resonance (MR) imaging-guided stereotactic method for guided microsurgical resection of either deep-seated gliomas or tumors adjacent to an eloquent area is described. The technique employs the Brown-Roberts-Wells stereotactic system and twist drills, 2.7 mm in diameter, for the stereotactic placement of 2.4 mm diameter scaled guidance catheters through the calvaria. In a patient with a deep-seated small glioma, less than 2 cm diameter, one catheter was implanted into the center of the enhanced mass through the cerebral cortex. In the other 14 patients, three to six catheters were used which made the tumor border clearer. After implantation of the guidance catheters, the stereotactic frame was removed and a standard open craniotomy performed. Target localization is not affected by brain movement, which is inevitable during open surgery. The tumor involved the frontal lobe in eight patients, the parietal lobe in two, and the thalamus in five. In all cases the lesion was quickly localized and radical removal was achieved. Neurological complications occurred in only one patient who suffered transient hemiparesis after the resection of a lesion in the pyramidal tract. The results demonstrate that microsurgery combined with CT- or MR imaging-guided stereotactic placement of guidance catheters is a new option for surgery of deep-seated gliomas or tumors adjacent to an eloquent area.

Key words: deep-seated glioma, magnetic resonance imaging-guided stereotaxis, guidance catheter

Introduction

Patients with gliomas treated by surgery and irradiation survive longer with a higher quality of life than those treated by radiation therapy alone. Stereotactic biopsy is appropriate in many patients with thalamic gliomas, but selected patients with significant mass effect from a solid tumor or a recurring cyst can benefit from resection. The goal of surgery is the resection of as much tumor as possible to improve any preoperative neurological deficits without causing new deficits. Deep-seated intra-axial tumors and tumors associated with the motor, visual, or speech areas present a special problem to the neurosurgeon who is attempting to preserve the patient’s neurological functions while trying to remove the neoplasm. Successful resection with minimal risk of unnecessary cortical or subcortical damage is dependent on the experience of the individual neurosurgeon.

Lesions sited deep below the cortical surface are difficult to locate and orient. In addition, the boundary between the tumor and the surrounding normal brain tissue is often unclear because of infiltration and edema, although well demarcated on computed tomography (CT) or magnetic resonance (MR) images. Localization of the tumor and boundary is time consuming. Intraoperative ultrasound is valuable for identifying large tumors, but is not useful for precise localization of the tumor boundary or for small tumors. A better surgical adjunct is needed to safely remove the tumor with minimal injury to unaffected brain.

Here we describe a new operative technique using guidance catheters implanted by CT- or MR imaging-guided stereotaxis through twist drill holes before standard craniotomy to locate deep-seated glioma or tumor adjacent to an eloquent area.
Materials and Methods

Fifteen patients with deep-seated tumors or tumor adjacent to eloquent areas underwent microsurgical tumor resection after the stereotactic placement of guidance catheters through twist drill holes (Radionics, Inc., Burlington, Mass., U.S.A.). A Brown-Roberts-Wells (BRW) CT stereotactic system (Radionics, Inc.) was used for the CT-guided stereotaxis. The BRW-MRIA-CW Cosman-Wells MR imaging adaptor (Radionics, Inc.) for the BRW CT stereotactic system was used for the MR imaging-guided stereotactic surgery, this adaptor is directly compatible with the other standard BRW components so that, once the target on the MR image was identified, it could be stereotactically approached in the same way as with the CT-guided method. Patients with poorly demonstrated gliomas on CT scans underwent MR imaging-guided stereotactic surgery.

Stereotactic CT or MR imaging was performed with the patient's head secured in an imaging-compatible stereotactic head holder. After intravenous contrast agent infusion, 5 mm axial CT or three-dimensional MR imaging slices were obtained through the area of interest. Several target points crucial to the operation were chosen. The number of points depended on the tumor size and location. In deep-seated small gliomas, of less than 2 cm diameter, one catheter was implanted into the center of the enhanced mass through the cerebral cortex. Three to six catheters were used in large tumors to make the border clearer. The goal of surgery was the radical removal of the contrast-enhanced mass (Fig. 1 upper), or removal of the high-intensity area on the T2-weighted image if the mass was not contrast enhanced and was located in a silent area (Fig. 1 lower).

The selection of the optimum and safest surgical approach to a tumor depends on its location and the identification of the relationship of the lesion to the surrounding tissue. The trajectory was chosen based on three-dimensional MR images and cerebral angiograms. The principal surgical approaches were as follows: A transfrontal approach for tumors located anterior to the pyramidal tract, basal ganglia, anterior thalamus, or pineal region; a temporoparietal approach for tumors deep to the trigone; and a parieto-occipital approach in parietal, occipital, or posterior thalamic tumors.

The system base ring was applied in the operating room with the patient under general anesthesia. The patient was then moved to the scanner unit for imaging and returned to the operating room with the BRW base frame in place. The imaging data were used to calculate the target points and the anterior/posterior, lateral, and vertical coordinates were then set on the arc system. The arc was attached to the base frame after the patient was steriley draped. A twist drill, 2.7 mm in diameter, was used for the stereotactic implacement of the guidance catheters through the calvaria. A scaled silicone catheter, 2.4 mm in diameter, was cut in advance so that the outer end would be flush with the cerebral surface to prevent displacement during the craniotomy (Fig. 2 upper). One catheter was implanted into the center of the enhanced mass through the cerebral cortex for deep-seated small gliomas. Several catheters were placed at the deepest boundary of the longest axis of the mass in large tumors, taking into account the presence of any vital structures. The distance between the cortical surface and the tumor, and the
path toward the tumor could be recognized with this scaled catheter when the corticotomy was performed, and the ideal cortical dissection was easily chosen because of the secure trajectory.

After implantation of the catheter was complete (Fig. 2 lower), the stereotactic frame was removed. Standard craniotomy and resection of the tumor using microsurgical techniques were performed. The actual resection of the lesion was independent of the stereotactic frame, so the procedure was free of bulky hardware in the operative field. The stereotactically implanted catheters defined the site of the cortical incision and the trajectory through the brain to the tumor and so directed the dissection precisely to the tumor site. Standard spatulas, 10-20 mm in width, attached to self-retainers, were used to create a corridor to the tumor (Fig. 3) by advancing them along the catheter path until the tumor was encountered (Fig. 4).

Results

Fifteen patients underwent microsurgical resection of either deep-seated gliomas or tumors adjacent to an eloquent area after stereotactic placement of guidance catheters through twist drill burr holes (Table 1). All lesions were clearly demonstrated by CT or MR imaging as relatively regular and round. The tumor was located in the frontal lobe in eight patients, the parietal lobe in two, and the thalamus in five. In one patient (Case 5), one catheter was implanted into the center of a deep-seated small glioma through the cerebral cortex. In the other 14 patients, three to six catheters were used. In all patients the lesion was quickly localized and radical removal was achieved as expected. Nine of the 10 patients who were neurologically normal preoperatively remained normal postoperatively. One pa-
tient (Case 6) suffered transient hemiparesis after the resection of the lesion in the pyramidal tract. Five patients presented with preoperative neurological deficits, three were unchanged and two were improved postoperatively. The procedure was always simple to perform and no complications were observed.

Representative cases are as follows.

**Case 5:** A 50-year-old male with bilateral grade III astrocytomas in the deep white matter presented because of head trauma. These tumors were incidentally found on CT scan. He was alert and neurologically normal on admission. MR imaging showed a 2 cm diameter cystic mass in the right centrum semiovale and a 5 mm diameter mass in the left centrum semiovale (Fig. 5 upper). He underwent MR imaging-guided stereotactic surgery with one catheter for navigation in the tumor in the right centrum semiovale. After removal of the tumor (Fig. 5 lower), interstitial brachytherapy was performed. The tumor on the left side was biopsied and coagulated by a monopolar lesion electrode. He was doing well after 12 months with no recurrence of the tumor on follow-up MR images.

**Case 6:** A 31-year-old male with a right frontal astrocytoma grade II was admitted with headache. He was neurologically normal on admission. MR imaging showed an isointensity area on the T1-weighted image and a high-intensity area on the T2-weighted image, without gadolinium-diethylenetriaminepenta-acetic acid (Gd-DTPA) enhancement (Fig. 6 upper). Four guidance catheters were implanted under MR imaging-guided stereotaxis. The tumor was removed with resultant transient left hemiparesis (Fig. 6 lower). He was doing well 10 months after operation without any neurological deficits.

**Case 8:** A 32-year-old male with a left frontal astrocytoma grade II was admitted following seizure. He was neurologically normal on admission. CT revealed a non-enhanced low-density mass in the left frontal lobe but did not demonstrate a clear tumor boundary. The mass was clearly identified as a low-intensity area on the T1-weighted MR image and a high-intensity area on the T2-weighted image. Gd-DTPA administration caused no enhancement (Fig. 7 upper). Three guidance catheters were implanted with MR imaging-guided stereotaxis. The tumor was grossly removed without resultant neurological deficits (Fig. 7 lower). He was well and asymptomatic 8 months after operation.

**Case 15:** A 21-year-old female with a right thalamic astrocytoma grade II presented with headache, left hemiparesis, and impairment of eye movement. Five catheters were implanted at the deepest boundary of the longest axis of the tumor. The tumor was resected via the right temporo-occipital approach, followed by radiotherapy (Fig. 8). Her signs and symptoms were improved.

**Discussion**

The techniques of stereotactic craniotomy and stereotactic excision of deep brain lesions have previously been described. The main disadvantage of these techniques is that the opening may be too small for larger lesions. Our technique is very useful and is very simple. No new or expensive instruments are required, only a CT- or MR imaging-guided stereotactic system with a stereotactic drill assembly, an operating microscope, and the usual microsurgical instruments. This idea is similar to the volumetric surgery of Kelly et al. combining...
Table 1  Summary of cases

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age/ Sex</th>
<th>Histological type</th>
<th>Tumor location</th>
<th>Neurological status</th>
<th>Follow-up status/ period (mos)</th>
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<td>Postop.</td>
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<tr>
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<td>rt parietal</td>
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<tr>
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<tr>
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<td>lt hemiparesis, eye movement disorder</td>
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</tr>
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</table>

*MR imaging-guided stereotactic surgery was performed.  G: grade.

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Fig. 5  Pre- (upper) and post-operative (lower) axial MR images in Case 5. left: T1-weighted image, center: T2-weighted image with Gd-DTPA, right: T2-weighted image. MR imaging-guided stereotactic surgery was performed with a guidance catheter for navigation implanted in right central semiovale lesion. The tumor was resected without resultant neurological deficits.
the microscope, laser, and computer simulation for image-directed tumor resection. Preoperative CT or MR images and many navigation systems and methods cannot always predict the intraoperative location of an intracranial lesion, because the lesions are often displaced or distorted by gravity, brain retraction, and cerebrospinal fluid aspiration during the intracranial procedure. We therefore implanted the catheter before craniotomy to reduce the potential localization error. Even minute tumors or irregularly shaped large tumors located in the deep white matter can be localized and resected accurately with our technique. The technique maintains the surgeon's orientation during both the approach and resection of preoperatively defined mass lesions.

The use of the twist drill made scalp incision unnecessary and shortened the time required to place the catheter. However, this procedure is done without visualizing the cerebral cortex so care must be taken not to cause injury to a cortical vein or artery. In our experience, no bleeding leading to complications has occurred, and we believe this can be avoided by choosing the appropriate entry point after precise preoperative planning. The entry point should avoid eloquent areas and major blood vessels. Any bleeding that does occur can easily be managed by the craniotomy. No seizures occurred in our patients.

The spatial accuracy of MR imaging has not been determined for stereotactic surgery. The potential image distortion from artifacts has lead to questions about the accuracy of MR imaging for stereotactic localization. Kondziolka et al. compared MR imaging-determined stereotactic target measurements with those obtained by CT to determine whether MR imaging provides a consistent and accurate method for obtaining stereotactic coordinates. They concluded that MR imaging-guided stereotactic localization can be used with confidence for most diagnostic, functional, and therapeutic stereotactic procedures. In our series no anatomical distortions or inaccurate stereotactic coordinates were caused by artifacts. The problems were mostly caused by catheter movement during formation of the skin or bone flap. To prevent such movement during craniotomy, the guidance catheter should be cut in advance near the cerebral cortex.

Fig. 6 Pre- (upper) and post-operative (lower) axial T1-weighted MR images in Case 6. left: T1-weighted image, center: T1-weighted image with Gd-DTPA, right: T2-weighted image.
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References


12) Shelden CH, McCann G, Jacques S, Lutes HR, Frazier RE, Katz R, Kuki R: Development of a com-

Fig. 7 Pre- (upper) and post-operative (lower) axial MR images in Case 8 with a left frontal astrocytoma grade II. *left*: T1-weighted image, *center*: T1-weighted image with Gd-DTPA, *right*: T2-weighted image. Three guidance catheters were implanted under MR imaging-guided stereotaxis. The tumor was resected without resultant neurological deficits.


Fig. 8 Pre- (upper) and post-operative (lower) coronal T1-weighted MR images with Gd-DTPA in Case 15 with a right thalamic astrocytoma grade II. Five guidance catheters were implanted under MR imaging-guided stereotaxis via the right temporo-occipital approach. The tumor was resected without resultant neurological deficits.

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