Research Article

Keyhole Tumor Removal Under Local Anesthesia

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Abstract

Objective: Surgery of the lesions involving eloquent cortex carries the risk of neurological deficits. We performed resection of the lesions under local anesthesia in order to prevent new neurological deficits.

Methods: We performed keyhole craniotomies under local anesthesia with stereotactic guidance. The eloquent areas were chosen using anatomical landmarks and functional MRI studies. The most distant gyrus from the eloquent brain area where the tumor is most superficial was chosen for cortical incision. The resection of the lesions was performed with cortical-subcortical stimulation and under continuous neurological examination. Postoperative MRI controls were taken within 24-72 hours and 3 months after the operation.

Results: In 92 patients functional MRI and stereotactic guidance were used for surgical planning. In 90% of the cases the lesions were totally removed. One patient died because of intracerebral hemorrhage, in 13 cases (14%) the surgery caused or worsened the neurological deficits. Three cases had permanent worsening. For the remaining cases the worsening was transient and resolved within a few days.

Conclusion: Stereotactic guidance with the help of fMRI provides safe tumor resection under local anesthesia alone through keyhole craniotomy.

Keywords: Keyhole craniotomy, local anesthesia, stereotactic, tumor

INTRODUCTION

Surgery of the lesions near or at the eloquent cortex carries high risk of neurological deficits. The precise cortical localization for critical neurological functions may vary significantly among individuals. Functional MRI (fMRI) provides cortical localization for motor, sensory and language functions (7). The extent of the tumor resection is an important determinant of prognosis for most of the intra-axial brain tumors (1,26,37). For tumor resections near motor and sensory cortices, we used keyhole craniotomies under local anesthesia with stereotactic guidance.
The purpose of this approach was to remove maximal amount of tumor located at or near the eloquent brain areas without causing any neurological deficit. Postoperative neurological deficits are due to edema, retraction, and/or resection of eloquent tissue. Performing the resection from a small craniotomy with the patient awake and with the use of cortical and subcortical stimulation, the surgeon may be able to minimize postoperative neurological morbidity. In our series, we used fMRI for surgical planning in order to facilitate radical resection of tumors located in functioning brain regions. Stereotactic guided tumor resections were performed with cortical and subcortical stimulation and under continuous neurological and language examinations

METHODS

Our patient population was composed of 92 patients who underwent stereotactic guided key-hole craniotomies under local anesthesia. Same neurosurgeon (SI) performed all of the procedures over the period 1999-2005. Data were collected in a retrospective manner. The surgery was performed with stereotactic guidance. Leksell G frame (Elekta, Sweden) was placed under local anesthesia. Axial, coronal and sagittal T1W and T2W, functional MRI and 3D Contrast-enhanced Magnetization Prepared Rapid Acquisition Gradient-Echo Imaging Sequence (MPRAGE) were performed (Fig. 1-A and 1-B). MPRAGE images were used for the estimation of stereotactic targets. After surgery, we used CT on same day and MRI examinations within 24-72 hours and 3 months for postoperative surgical control (Fig 1-C).

**Figure 1:** A) Preoperative coronal and B)axial MR images demonstrating a tumor in the right precentral gyrus. C) fMRI (BOLD) image showing motor cortex – tumor relations. D)Postoperative image showing total tumor removal

**fMRI technique:** T1W (TR/TE/FA: 630/14/70) and T2W (TR/TE/FA: 3800/90/180) axial images were taken with Siemens Symphony Vision upgraded to Leonardo. The blood oxygen level-dependent (BOLD) MR imaging technique parameters were as follows TR/TE/FA: 1.68/64/90, matrix: 64x128, slice thickness: 3 mm, slice number: 100. The patients were informed about the hand movements, and patients practiced the movements prior to the fMRI procedure. During fMRI finger opening, closing and resting movements were repeated 5 times with 18 sec intervals. Images obtained before activation were subtracted from the images obtained after activation (Fig. 1-D).

The eloquent areas were chosen by means of anatomical landmarks and functional MRI studies. Axial T1W, T2W and MPRAGE images were transferred to HP workstation. Surgiplan stereotactic planning program (version 2.01-2.10 Elekta Sweden) was used first to check the accuracy of the MR images and then to plan of the surgical targets and strategies. Gyri and sulci located nearby the eloquent areas were inspected. The most distant gyrus from the eloquent brain area where the tumor is most superficial was chosen for cortical incision. The coordinates were calculated on the MPRAGE images on which MRI distortion is minimal.

**Anesthesia and surgical technique:** Preoperative assessment should be done
carefully in patients undergoing craniotomy under local anesthesia. If the patient is confused or has communication difficulties, extreme anxiety, inability to lie still for a long time, awake craniotomy procedure is contraindicated. The patients should have been given detailed information on the procedure and anesthesia technique. Operation team must be also informed previously to obtain a calm atmosphere in the operation room during surgical procedure. Surgical and anesthetic management of all awake craniotomy cases were performed by the same neurosurgeon and anesthesiologist. Leksell stereotactic frame was applied under local anesthesia, using 0.5% lidocaine with epinephrine 1:200000. After the MRI procedures and stereotactic planning the patient was transferred to the operation room. During surgery analgesic and anxiolytic agents were used for some patients. Full cardiac and respiratory monitoring was used for the patients by the anesthesiologist. Leksell stereotactic frame with fixed head was connected to the Mayfield head holder with a Mayfield adapter. After routine skin preparation the head was covered with sterile drape and the surgical area was separated from the site of the anesthesiologist with transparent sterile nylon. With this draping technique the patient does not express discomfort and the surgeon is able to see the patient’s hand and leg movements.

A local anesthetic at a total volume of 12-30 ml was used for scalp block. We performed the scalp block with a mixture of 0.25% bupivacaine and 1% lidocaine with 35 µg of epinephrine. In the case of any discomfort expressed by the patient additional sedative agents (2 µg/kg fentanyl and 30 µg/kg midazolam) were administrated intravenously (needed for six patients). 20% Mannitol at a dose of 0.25mg/kg, 8 mg of dexamethasone and prophylactic antibiotics were given intravenously preceding the scalp incision.

All operations were performed with the operation microscope. During the tumor removal continuous brain retraction was not used in order to avoid complications related to retractor pressure (21).

The bone opening was two centimeter in diameter for a tumor of which diameter was less than 3 cm. Following a 3-4 cm linear skin incision drill-hole was enlarged to 2 cm, and the dura opened in cruciate fashion (Figure 2). If the tumor diameter was more than 3 cm (max. size was 5.4 cm) the bone opening was 3 cm with a skin incision of 6-7 cm. The aim for a bigger craniotomy in bigger tumors was to provide chance to inspect the peritumoral cavity in various directions and to be able to see the entire cavity boundaries. Following dural opening the cortex under vision was stimulated with bipolar stimulation (Elekta RF lesion generator) in order to map the cortex to decide whether there was an eloquent area under the preoperatively planned pathway. The stimulation parameters were 60-100 Hz, pulse duration 250 ms and 2-5 sec. The current was incrementally increased from 1 to 8mA. The cortex planned for the cortical incision was stimulated. The neurological examination and language testing was performed by the anesthesiologist or another neurosurgeon.

**Figure 2:** Intraoperative photograph showing 2 centimeter bone opening for a tumor of which diameter was less than 3 cm.
Stereotactic coordinates of the target cortical incision are helpful only at the beginning of the surgery. After arachnoidal opening even a small amount of CSF drainage can cause inaccuracies in gyral coordinates. Following the decision of the safe entry point, the sulcus adjacent to the gyrus is gently dissected; separated, the gyral surfaces are stimulated. Cortical incision was done at the deepest point nearest to the tumor.

The surgery was continued with the patient awake and the patient was frequently asked to speak or move his extremity. Resection of metastatic and high grade glial tumors resection was not challenging. These tumors are generally well demarcated. First step of tumor removal was tumor debulking. Tumor resection was aggressively continued until the onset of neurological dysfunction. During tumor debulking maximum effort was made to stay inside of the tumor margins. In the subjects without any neurological dysfunction during the resection, the peritumoral edematous white matter was reached. The exposed peritumoral edematous area was stimulated and tissues thought as remnants was resected in order to achieve a total resection.

Resection of the low grade gliomas was more complicated. During the resection of the tissue in which we were uncertain whether it was a safe area to resect, stimulation was repeated to protect the axonal projections arising from the eloquent cortex or internal capsule. During low grade glioma resection surgeon can deteriorate if he is in or out of the tumor area; in such situation ongoing neurological and language examinations are important. The continuous examinations help minimize the potential neurological morbidity caused by injury to axonal projections originating from eloquent cortex.

RESULTS

A total of 92 patients underwent craniotomy with local anesthesia alone over the period between 1999-2005. Patients’ ages ranged from 17-76 years. 47 patients presented with seizures, 9 with symptoms from mass effect, 12 with focal neurological deficit, and 24 were asymptomatic.

Complications are: Epileptic seizure occurred during surgery in two patients (2.2%). One of these patients had seizure during cortical stimulation; the other one had seizure during tumor removal from the motor cortex. With intravenous diazepam and mannitol administration the patients recovered and the surgery was continued without any problem.

One patient (1.1%) with glioblastoma multiforme (GBM) died of postoperative intracerebral hemorrhage. In another patient after partial tumor removal, midline shift occurred. The patient was stuporous and hemiparesia was noticed. Control MRI showed partial tumor removal, peritumoral edema and midline shift. The patient was reoperated within 48 hours and antiedema medication was given. Unconsciousness and the hemiparesia resolved completely in three days. In one patient with grade 2 astrocytoma weakness occurred during surgery. This was ignored and the remnant tumor tissue was removed. The operation was completed with development of severe hemiparesia. For another patient the surgical entry point was planned to be at the interhemispheric fissure at the nearest point to the tumor. Some CSF leakage occurred because of the dissection performed beneath a drainage vein. After the dissection stereotactic guidance was used. The cortex underlying the preoperatively planned coordinates was incised but the tumor could not be found and the patient’s movements became weak. The surgery was terminated. Control MRI showed that cortical incision was at the adjacent gyrus. The CSF leakage led to shift of the cortex and misdirection. The reoperation was performed one week later and the tumor was totally removed. Cortical stimulation prior to cortical incision was added to the procedure in all cases following this one. The stereotactic entry point was marked at the beginning of the surgery and stereotactic guidance was rarely used during the tumor removal.

During tumor removal some patients expressed weakness or heaviness at their extremity, upon this surgery was stopped and the tumor cavity was stimulated. In three cases in which deficit was due to traction over a rubber like tumor the weakness or speech
problem resolved in minutes. The surgery was continued with care and gentle ultrasonic tumor removal or step by step bipolar cautery-section-bipolar stimulation. In other seven cases with softer tumors (anaplastic astrocytoma and GBM) who expressed weakness in their extremity during the aggressive tumor resection, the careful inspection of the cavity showed that we were out of the tumor boundaries, after bipolar stimulation the direction of the tumor removal was changed in order to resect the residual tumor, or it was understood that tumor removal was completed\(^{(13,14)}\). Three (3.2\%) of these patients had permanent worsening of deficits. Surgery was performed without any intraoperative or postoperative complications in all of the remaining patients (Table 1).

**Table 1:** Intraoperative worsening of the neurological deficits.

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<thead>
<tr>
<th>Neurological Deficits</th>
<th>Number (%)</th>
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<tbody>
<tr>
<td>Permanent worsening</td>
<td>3 (3.2%)</td>
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Different histopathological diagnoses were encountered. Most of the cases were metastatic (39 cases) and 34 were high grade astrocytoma (23 glioblastoma multiforme, 11 anaplastic astrocytoma), 12 were low grade glioma and 7 were cavernoma. Postoperative MRI controls showed total resection (radiological total) in all cases of cavernoma, 38 of metastasis (97.5\%), and 30 of high grade astrocytoma (88.2\%) cases. 8 of the low grade glioma (66.6\%) cases were resected totally. In four (33.4\%) of the low grade glioma cases the resection was subtotal or partial (Table 2).

**Table 2:** Total / partial resection of the tumor and the correlation with histopathological diagnosis

<table>
<thead>
<tr>
<th>Histopathological Diagnosis</th>
<th>Total / Partial Resection</th>
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<tr>
<td>Cavernoma</td>
<td>Total</td>
</tr>
<tr>
<td>Metastasis</td>
<td>Total (97.5%)</td>
</tr>
<tr>
<td>High grade astrocytoma</td>
<td>Total (88.2%)</td>
</tr>
<tr>
<td>Low grade glioma</td>
<td>Subtotal (33.4%)</td>
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DISSCUSSION

Resection of intrinsic brain tumors located in close relationship with eloquent cortex carries high risk of postoperative deficits. The definition of eloquent area included precentral gyrus, central sulcus, postcentral gyrus, supplementary motor area, dominant hemisphere frontal operculum and angular gyrus (26). Intraoperative MRI, frame based or image guided stereotactic tumor resection techniques, smaller cranial and dural openings, minimal exposure of normal brain, intraoperative stimulation techniques can be used to tailor the extend of resection and reduce the risk (5,15,45). Advantages of key-hole techniques include opportunity of tumor resection with local anesthesia, shortened operation duration and hospital stay, decreased healthcare costs, and a rapid convalescence and rehabilitation (6).

Jones and Smith (18), described three anesthetic techniques for awake craniotomy. These techniques are local anesthesia alone, sedation techniques and asleep-awake-asleep techniques. Minor procedures such as stereotactic biopsy can be performed with drill-hole or burr-hole and adequate local anesthetic infiltration into the operation area of scalp, pericranium and dura (12). If a routine craniotomy is performed, field block of the scalp has been suggested (9). In sedation technique, combination of propofol and remifentanil is widely used during awake craniotomy due to their short elimination half-life (10,11,19,20,24,25,34).

In sedation technique, dexmedetomidine, an alpha-2 adrenoreceptor antagonist, has been suggested recently to use in patients undergoing awake craniotomy. It has been shown that dexmedetomidine provided adequate levels of analgesia and sedation during cortical mapping and tumor resection (2,23). Jaaskelainen has stated that most patients are horrified when the idea of awake cranial surgery is first put to them. However with repeated reassurance and careful explanation of the procedure, by the time the surgery is performed the patients have confidence in the medical team (17). Whittle’s study has confirmed previous published work that the majority of patients tolerate an awake craniotomy very well (43). Bipolar stimulation is mandatory before the cortical incision (36).

Zentner et al. reported that intraoperative electrophysiological monitoring remained normal in all patients experiencing SMA deficits (45). Russel and Kelly used volumetric stereotactic tumor resection technique instead of awake or asleep intraoperative monitoring techniques for SMA lesions (30,32). Different eloquent brain areas have diverse characteristics, therefore intraoperative electrophysiological monitoring is inadequate for some cases. We performed tumor resection guided with cortical-subcortical stimulation and continuous neurological examination. During tumor resection the anesthesiologist or another neurosurgeon performs continuous neurological examination (27).

The theoretical advantages of radical tumor resection include reduction of intracranial pressure and improved quality of life, reduction of tumor mass which facilitates the effect of adjuvant therapy, increased possibility of an accurate pathological diagnosis, decreased rate of recurrence for a
metastatic or high grade tumor and reduced risk of dedifferentiation of a lower-grade tumor. The median survival time and time to recurrence are improved in patients who undergo aggressive resection (37,42,44). The surgeon must often provide a balance between these theoretical benefits of an aggressive resection and the postoperative neurological morbidity (41,43). Despite the risks of surgery in eloquent brain areas, maximal tumor excision is an important determinant of prognosis for most brain tumors. In our series the surgery of metastatic and high grade glial tumor was not challenging. These tumors are generally well demarcated. First step of tumor removal was tumor debulking. Tumor resection was aggressively carried on until the achievement of total resection or the onset of neurological dysfunction. In the subjects without any neurological dysfunction during the resection, the aim of the surgeon was to reach the peritumoral edematous white matter. When the periphery of the tumor is exposed without any neurological deficit by stimulating this surface the surgeon can safely remove the tissues considered as tumor remnants. Low grade glial tumor surgery is more challenging. Tumor removal is carried out with ultrasonic aspirator. Traction of the tumor with a tumor forcesp causes transient paresis. Frequent task performance and bipolar stimulation is ad vantageous to achieve complete resection without any deficit.

In conclusion, stereotactic guidance with the help of fMRI provides safe tumor resection with local anesthesia alone via a keyhole craniotomy. Authors believe that surgical removal of the cortical or sub-cortical intracranial masses can be successfully made by stereotactic guiding awake-surgery with local anesthetically agents (40).

REFERENCES


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