Gamma Knife surgery for focal brainstem gliomas

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Object. Focal tumors, a distinct subgroup of which is composed of brainstem gliomas, may have an indolent clinical course. In the past, their management involved monitoring of open-ended imaging studies and shunt placement if cerebrospinal fluid diversion was required. Nonetheless, their treatment remains a significant challenge for neurosurgeons. Gamma Knife surgery (GKS) has recently been tried as an alternative to surgical extirpation. In the present study the authors assess clinical and imaging results in 20 patients who harbored focal brainstem gliomas treated with GKS between 1990 and 2001.

Methods. There were 10 male and 10 female patients with a mean age of 19.1 years. Sixteen tumors were located in the midbrain, three in the pons, and one in the medulla oblongata. The mean tumor volume at the time of GKS was 2.5 cm³. In 10 cases a tumor specimen was obtained either by open surgery or stereotactic biopsy, securing the diagnosis of pilocytic astrocytoma in five patients and nonpilocytic astrocytoma in five others. In the remaining 10 cases, the diagnosis was based on clinical and neuroimaging findings. The prescription Gamma Knife dose varied between 10 and 18 Gy, except in three patients who were receiving a boost to a site in which external-beam radiation was previously delivered. An average of four isocenters were utilized per GKS.

Patients were followed up for a mean of 78.0 months. The tumors disappeared in four patients and shrank in 12 patients. Of these patients, one experienced transitory extrapyramidal symptoms and fluctuating impairment of consciousness (from somnolence to coma) for 6 months. Another patient whose tumor disappeared 3 years following GKS died of stroke 8 years postoperatively. The rest of the patients either remained stable or improved clinically. Tumor progression occurred in four patients; of these four, one patient developed hydrocephalus requiring a ventriculoperitoneal shunt, two showed neurological deterioration, and one 4-year-old boy died of tumor progression.

Conclusions. Gamma Knife surgery may be an effective primary treatment or adjunct to open surgery for focal brainstem gliomas.

KEY WORDS • low-grade glioma • pilocytic astrocytoma • brainstem • Gamma Knife surgery • radiosurgery

Clinical Material and Methods

Patient and Tumor Characteristics

Between February 1990 and October 2001, 20 patients with focal brainstem gliomas were treated with GKS at the University of Virginia Health System’s Lars Leksell Center for Gamma Surgery (Table 1). The study population consisted of 10 male and 10 female patients, with a mean age of 19.1 years (median 13 years, range 4–64 years). All patients presented with progressive tumor growth and/or neurologic deficits. The focal tumors were located in the midbrain in 16 patients, the pons in three, and the medulla oblongata in one. Of 16 midbrain tumors, 13 were located in the tectum, two in the tegmentum, and one in the cerebral peduncle. Three midbrain tumors also involved the rostral pons, and one invaded the basal thalamus. All gliomas were intrinsic tumors with the exception of two that were postoperative residuals of dorsal exophytic tumors.

Symptoms of increased intracranial pressure caused by obstructive hydrocephalus were the most common clinical manifestations of the focal tumors; these symptoms were...
Gamma Knife surgery for brainstem gliomas

### TABLE 1

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* Bx = biopsy; FU = follow up; Re = resection.
† Symptom classification: 1 = long tract signs, 2 = cranial nerve palsies, 3 = cerebellar symptoms, 4 = hydrocephalus, 5 = headache, 6 = seizure.
‡ Pathological diagnosis was graded according to the World Health Organization tumor classification.
§ Patient underwent fractionated radiotherapy at a dose of 18 Gy. (read: "57 Gy")
|| Patient underwent fractionated radiotherapy at a dose of 64.5 Gy.

Gamma Knife Surgery Technique

The GKS procedure has been detailed elsewhere. In pediatric patients, the placement of the stereotactic frame and the entire treatment procedure were performed after induction of general anesthesia. In adult patients, a local anesthetic supplemented with intravenous sedation was used only during the placement of the frame. Before 1990, CT scanning was the only imaging modality available for treatment planning; after 1990, MR imaging was used. Until July 2001, GKS was performed using the Leksell Gamma Unit, model U, and thereafter the C model was used (Elekta Instruments, Inc.). The dose rate varied, ranging from 3.66 Gy/minute in March 1989 to 1.59 Gy/minute in October 1995, when the cobalt source was reloaded, and from 3.56 Gy/minute in November 1995 to 2.31 Gy/minute in July 2001, when the model C was installed. The dose rate of the model C unit ranged from 3.67 Gy/minute in July 2001 to 3.55 Gy/minute in October 2001. The KULA software was used for dose planning from 1989 to June 1994, and was then replaced with GammaPlan software (Elekta Instruments, Inc.).

A mean dose of 12.8 Gy (median 13.5 Gy; range 4–18 Gy) was given to the tumor margin prescribed to an isodose configuration ranging from 30 to 70% (median 45%). The mean maximum dose was 29.8 Gy (median 30 Gy, range 10–43.3 Gy). The average number of isocenters used per patient was four (range 1–9 isocenters). The peripheral doses varied between 10 and 18 Gy, except in two adult patients with additional fractionated radiotherapy (one given 64 Gy).
Gy and the other given 40 Gy) and one patient with planned but unfulfilled radiotherapy (due to patient’s refusal); these three patients received only boost doses of 4, 7, and 5 Gy, respectively.

**Follow-Up Evaluation**

Clinical follow-up data were obtained by examining the patients, communicating verbally, or in writing with the patients and the referring physicians. Follow-up MR imaging was repeated every 3 months for the first year and thereafter at 6-month intervals. Additional imaging studies were performed in the interim if the patients developed new or worsening clinical symptoms. Special software that was developed at our center was used to calculate tumor volumes seen on all films, and these calculations were reviewed by neurosurgeons and neuroradiologists. The reliability of the calculation method depends on the numbers of slices that show the tumors.46 Other changes noted during imaging studies were also detailed and recorded.

**Statistical Analysis**

Imaging outcome was analyzed using the nonparametric independent t-test for univariate analysis of continuous variables (age, KPS score, peripheral dose, maximum dose, isodose configuration, number of isocenters, tumor volume, interval duration between the diagnosis of brainstem tumor and GKS, and duration of imaging follow up) and the chi-square test for dichotomous variables (sex, pilocytic or non-pilocytic tumor [pathology], tectal or nontectal location, enhancing or nonenhancing tumor, and degree of increased enhancement in the tumor following GKS). Logistic regression was used for multivariate analysis. The tumor control rate was analyzed using the Kaplan–Meier method. All statistical analyses in the study were performed using a commercially available software package (SPSS version 10.1; SPSS, Inc.). Statistical significance was set at a probability level of less than 0.05.

**Results**

**Illustrative Cases**

*Case 1.* This 56-year-old woman had a tectal tumor with obstructive hydrocephalus. She had been asymptomatic following insertion of a shunt. Fractionated radiation was performed with a total dose of 64.8 Gy, but tumor progression prompted GKS in 1993 with 4 Gy to the tumor margin. The tumor started to shrink 9 months after GKS and disappeared completely 3 years postoperatively (Fig. 1). She remained free of symptoms following radiosurgery but died of a hypertensive hemorrhage in the left basal ganglion 8 years later.

*Case 4.* This 19-year-old woman with a midbrain tumor received a VP shunt for hydrocephalus without a mass lesion identified on CT scan. During a shunt revision 5 years later, MR imaging revealed a mass at the rostral part of the quadrigeminal plate and posterior wall of the third ventricle (Fig. 2). Gamma Knife surgery was performed with a peripheral dose of 13 Gy (maximum dose 43.3 Gy). After treatment, she presented with extrapyramidal symptoms and fluctuating impairment of consciousness (from somnolence to coma) for 6 months. Follow-up MR imaging showed the same tumor size, but diffuse high-signal changes involving bilateral fornices on FLAIR images. It was unclear whether this finding represented radiation-induced changes or artifacts occasionally seen on FLAIR images. Nonetheless, these changes did not explain her serious clinical condition. She was treated with steroids, and eventually made a complete recovery. At the last follow up in 2004 she was asymptomatic, and the tumor as well as the previ...
ous signal changes had disappeared completely on MR images.

Case 6. This 9-year-old girl had an 18-month history of headache, nausea, and vomiting. A CT scan revealed a partially enhancing lesion at the tectal area causing hydrocephalus (Fig. 3). A stereotactic biopsy procedure enabled the diagnosis of a nonpilocytic, low-grade glioma in the patient. She underwent insertion of a VP shunt in 1989. Progression of the tumor prompted treatment with GKS with a peripheral dose of 15.4 Gy. The tumor shrank progressively and disappeared 7 years after treatment. The patient has remained free from symptoms after 15 years of follow up, and is now a college student achieving excellent academic performance.

Case 8. This 7-year-old boy had a 1-month history of right-sided weakness, and was diagnosed with a midbrain tumor in January 1992 (Fig. 4). Tumor resections were performed in February and March of 1992; the tumors were found to be pilocytic astrocytomas, and the patient showed some clinical improvement after resection. Gamma Knife surgery was performed in October 1993 because of progression of the tumor and recurrent neurological deficits. A dose of 12 Gy was delivered to the periphery of the tumor, and follow-up imaging 6 months later showed a decrease in tumor size. Ten months after GKS treatment, the patient’s right-sided hemiparesis and diplopia worsened and he experienced impaired consciousness. Magnetic resonance imaging revealed an enlarging tumor with cystic necrosis and surrounding edema, which prompted a surgical decompression. He recovered uneventfully from the surgery and is now a basketball player with only mild muscle atrophy in his right hand. There was no evidence of tumor recurrence in this patient on the latest MR images 11 years after treatment.

Imaging Outcome

The mean follow-up duration in all patients was 78.0 months (range 5–180 months). Follow-up duration was 15 years in one patient, 12 years in one, 11 years in two, 9 years in one, 8 years in one, 6 years in three, 5 years in four, 4 years in three, 3 years in two, and less than 2 years in two patients. As assessed using MR imaging, the tumors disappeared in four patients, shrunk more than 75% in another six, and decreased in the range of 25 to 75% in six patients. The mean duration until the onset of tumor shrinkage was 14.8 months (range 3–46 months).

Four patients had tumor progression. Two patients who initially responded to GKS had tumor regrowth at 10 and 41 months of follow up, respectively. A tumor progressively enlarged in a patient in whom fractionated radiation therapy was planned but failed following GKS with a low peripheral dose of 5 Gy. The fourth patient died of tumor progression.

The univariate analysis identified the following variables as correlated with better tumor response: higher KPS score, higher peripheral dose, smaller tumor volume, and longer symptom duration before GKS. On multivariate analysis, only KPS score correlated with tumor response (Table 2).

In addition to a change in tumor size, enhancement of the tumor increased in 10 patients between 3 and 18 months of follow up. The onset of increased enhancement occurred after a mean follow up of 6.4 months and ended after a mean follow up of 29.3 months (range 10–48 months). The increase in tumor enhancement did not predict tumor control. An area of low intensity surrounding the tumor on T1-weighted MR imaging occurred in eight patients at a mean duration of 5.3 months after GKS and ended after a mean duration of 14.3 months. These imaging changes were independent of target volume or radiosurgical dose. None of the patients developed new clinical symptoms correlated with these imaging changes except for one patient with transient headache.

Clinical Outcome

Of the nine patients whose only symptoms were associated with hydrocephalus and who were successfully treated with a VP shunt before GKS, one patient died of tumor progression and eight were asymptomatic at the last follow up. The patient in Case 4 developed radiation-induced changes with high-signal intensity on FLAIR images and experienced transient extrapyramidal symptoms and impaired consciousness following GKS. In Case 7, the patient had
mild memory loss and ataxia due to hydrocephalus, and the tumor progressed in spite of GKS. A VP shunt relieved the symptoms in this patient.

Of the nine patients with neurological deficits due to local tumor mass effects, in seven the tumor shrank and the neurological deficits improved after GKS. Two patients who initially had improvement of deficits had deterioration in their conditions due to tumor progression. One patient with only mild headache and another with asymptomatic neurofibromatosis at the time of GKS were free of symptoms after a decrease in the size of the tumor. The graph in Fig. 5 shows the tumor progression-free survival rate of all 20 patients (84%) after 5 years.

Discussion

Brainstem gliomas, accounting for only 2% of adult brain tumors, constitute 10 to 20% of central nervous system tumors in the pediatric age group.13,17 Due to their critical location, brainstem gliomas have been considered the most difficult brain tumors to treat. Before MR imaging, conventional radiotherapy or chemotherapy were used without considering the histological or biological characteristics of the tumor, and usually yielded disappointing results. After the availability of MR imaging and the accumulation of knowledge regarding the correlation between clinical presentations, tumor locations, growth patterns, and patient outcomes, brainstem gliomas were divided into several subgroups with distinct biological behaviors17,21 instead of being categorized as a homogenous pathologic entity. A variety of classification schemes have been proposed, which can essentially be succinctly divided into diffuse or focal tumors.11,21

**Diffuse Brainstem Gliomas**

Diffuse intrinsic tumors constitute the majority (75–85%) of brainstem gliomas.17 These tumors typically exhibit an aggressive biological course and indicate the most serious prognosis. Neither surgery nor radiotherapy has a role in the management of these tumors,1,5,10,29 and radiosurgery is not an appropriate alternative either.

**Focal Brainstem Gliomas**

Focal brainstem gliomas are divided into tectal, cervicomедullary junction, and dorsally exophytic tumors; infrequent locations of focal gliomas include the tegmentum, pons, and medulla oblongata.17,21 These tumors are typically indolent, developing potentially dangerous long tract and
cranial nerve symptoms. Occasionally, obstruction of the aqueduct causes the initial symptoms of hydrocephalus and increased intracranial pressure, prompting imaging studies that lead to the diagnosis.

There are four treatment alternatives for managing focal brainstem gliomas. These four options are: 1) shunting and open-ended follow up with neuroimaging; 2) fractionated external beam radiation or brachytherapy; 3) tumor resection; and 4) GKS.

**Shunting and Open-Ended Follow Up With Neuroimaging.** Cerebrospinal fluid diversion (shunting) if necessary and periodic MR imaging monitoring have been reported as satisfactory management options of focal brainstem gliomas in most cases. Investigators have reported an uneventful clinical course in patients with focal gliomas managed using this treatment approach, with a mean follow up between 2.6 and 7 years. A small tumor size and a lack of contrast enhancement on MR imaging had been proposed as predictors of a benign clinical course, however, these predictors could not be confirmed either by us or other patient series.

**Fractionated External Beam Radiation or Brachytherapy.** Authors have reported successful results with fractionated radiotherapy in small patient series, but generally, conventional radiotherapy with or without combined chemotherapy has limited efficacy. Moreover, in pediatric patients, the side effects of these treatments are significant. Brachytherapy, as reported by Mundinger and colleagues, yielded 5-year patient survival rates with iodine-129 or iodine-125 of 27% and 55%, respectively.

**Tumor Resection.** With the advancement of microsurgical techniques and neurophysiological monitoring, brainstem tumors are no longer considered surgically inaccessible and several authors have reported impressive results using these techniques. However, it is difficult to interpret these data because some patient series are small and most studies are retrospective.

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**Fig. 4. Case 8.** Axial contrast-enhanced T₁-weighted preradiosurgical (A) and postradiosurgical (B–D) MR images. A: Image showing a hypointense residual tumor involving the left cerebral peduncle. B: Six months after GKS, the tumor is diminished in size and strongly enhancing. C: Ten months after treatment, the tumor is enlarged and consists mainly of cystic necrosis within the tumor. D: Follow-up image obtained 11 years after the patient underwent decompression surgery, showing a postoperative cavity without evidence of tumor recurrence.
include heterogeneous tumor pathology and location. Lesniak et al.\textsuperscript{27} reported survival rates longer than 10 years in all 30 patients with pilocytic astrocytomas and a 22-month median survival rate in 10 patients with fibrillary astrocytomas. In this patient series, 16 patients with pilocytic astrocytomas had tumor recurrence requiring additional surgery or adjuvant radiotherapy, and the overall morbidity rate was 17.5\% with moderate disability, 3.5\% with severe disability and 1.7\% in a vegetative state.

\textit{Gamma Knife Surgery}. Gamma Knife surgery, originally designed to manage deep intracranial lesions, has emerged as a treatment alternative for focal brainstem gliomas.\textsuperscript{15,20,24} Fuchs and colleagues\textsuperscript{15} treated 12 patients with low-grade brainstem gliomas using GKS and attained tumor control in 11 patients (absent or smaller in six patients, no change in five, and tumor increase in one patient). Kihlstrom and colleagues\textsuperscript{24} also reported satisfactory results of GKS in six of seven patients with tumor regression. In the present study, a decrease in size or complete disappearance of the tumor occurred in 16 of 20 patients. The mean duration of follow up in our patient series was 6.5 years, but the natural progression of some of these tumors could be even longer. Therefore, open-ended neuroimaging monitoring will be needed to assess whether the present results will remain consistent in the course of long-term follow up. The outcomes of different approaches for focal brainstem gliomas are summarized in Tables 3 and 4.

\textbf{Dose Selection for Gamma Knife Surgery}

In the early data of Kihlstrom et al.,\textsuperscript{24} tumor control was achieved in six of seven patients treated with GKS doses ranging from 14 to 35 Gy, yet the incidence of radiation-induced changes or necrosis accompanied by neurological deficits was high. Six patients developed radiation-induced reactions; one had permanent sequelae and five had tran-

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### TABLE 3

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<td>May et al., 1991</td>
<td>6</td>
<td>tectum</td>
<td>none</td>
<td>7.6 yrs</td>
<td>shunt only</td>
<td>normal (5); development delay (1)</td>
<td>stable in size</td>
</tr>
<tr>
<td>Mundinger et al., 1991</td>
<td>54†</td>
<td>brainstem</td>
<td>Grade I, II</td>
<td>NA</td>
<td>brachytherapy w/ iodine-125 or iodine-129</td>
<td>5-yr survival rates = 54.8% (iodine-125) vs 6.9% (iodine-129)</td>
<td>NA</td>
</tr>
<tr>
<td>Vandertop et al., 1992</td>
<td>12</td>
<td>midbrain</td>
<td>Grade II</td>
<td>2.5 yrs</td>
<td>partial resection ± radiotherapy</td>
<td>excellent (9); improved (2); stable (1)</td>
<td>partial resection (9); minimal resection (2); Bx (1) free of tumors (4); 50% reduction (1) unchanged (4); malignant transformation (1)</td>
</tr>
<tr>
<td>Edwards et al., 1994</td>
<td>5</td>
<td>pons</td>
<td>Grade I</td>
<td>4.8 yrs</td>
<td>Bx &amp; radiotherapy, 5400 cGy endoscopic Bx or partial resection &amp; 3rd ventriculostomy surgery; radiotherapy for residual &amp; malignant tumors</td>
<td>free of symptoms (4); facial paresis (1) all improved</td>
<td>total resection (19); subtotal resection (12); partial resection (4)</td>
</tr>
<tr>
<td>Oka et al., 1999</td>
<td>5</td>
<td>tectum</td>
<td>low grade</td>
<td>3.4 yrs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wang et al., 2000</td>
<td>35</td>
<td>midbrain</td>
<td>low–high grade</td>
<td>28 mos</td>
<td></td>
<td>died (2); back to work (6); live independently (17); live dependently (3); unknown (7)</td>
<td>total resection (19); subtotal resection (12); partial resection (4)</td>
</tr>
<tr>
<td>Lesniak et al., 2003</td>
<td>40‡</td>
<td>brainstem</td>
<td>Grade I, II§</td>
<td>10 yrs</td>
<td>Grade I surgery; Grade II surgery &amp; radiotherapy, chemotherapy</td>
<td>Grade I: alive after 10 yrs (30); Grade II: median survival of 22 mos (10)</td>
<td>Grade I: total (25); near-total resection (5); Grade II: near total (2); subtotal resection (8)</td>
</tr>
</tbody>
</table>

\* NA = not applicable.
† Seventy percent of patients with circumscribed tumors.
‡ Thirty with Grade I tumors, 10 with Grade II.
§ Sixteen patients with recurrence.
Gamma Knife surgery for brainstem gliomas

### Table 4

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Patients</th>
<th>Peripheral Dose (mean/range)</th>
<th>Tumor Location (no. of patients)</th>
<th>FU Period</th>
<th>Tumor Outcome (no. of patients)</th>
<th>Clinical Outcome (no. of patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kihlstrum et al., 1994</td>
<td>7</td>
<td>14–30 Gy</td>
<td>tectum (6)</td>
<td>6.9 yrs</td>
<td>disappearance (4), regression (2), progression (1)</td>
<td>improved (4), no change (2), sequelae (1)</td>
</tr>
<tr>
<td>Fuchs et al., 2002</td>
<td>12</td>
<td>12 Gy/9–20 Gy</td>
<td>midbrain (5), pons (6), medulla (1)</td>
<td>41 mos</td>
<td>absent or smaller (6), no change (5), larger (1)</td>
<td>improved (4), stable (3), worse (2), dead (3)</td>
</tr>
<tr>
<td>Yen et al., 2007</td>
<td>20</td>
<td>12.8 Gy/4–18 Gy</td>
<td>midbrain (16), pons (3), medulla (1)</td>
<td>78.0 mos</td>
<td>disappearance (4), regression (12), progression (4)</td>
<td>improved (8), stable (9), worse (3)</td>
</tr>
</tbody>
</table>

Sient neurological deterioration. These investigators subsequently recommended that the dose of GKS should be no greater than 14 Gy for low-grade gliomas. In the patient series reported by Fuchs and colleagues, a peripheral dose of GKS ranging from 9 to 20 Gy (mean 12 Gy) produced good outcomes without complications. The peripheral dose of GKS we used ranged from 10 to 18 Gy, which appeared to be a safe dose that yielded reasonable results. The dose–response effect was not clear from our limited number of patients; however, a higher peripheral dose seemed to be more effective.

**Intratumoral Changes in Enhancement**

Increased enhancement of the tumor on MR imaging after GKS is presumably due to the breakdown of the blood–brain barrier and possibly indicates a positive outcome. This imaging enhancement appeared in all patients treated by Kihlstrum et al., who used peripheral doses between 14 and 35 Gy, and in 10 of 16 patients in our series who had a partially enhancing or nonenhancing tumor before GKS. In the present study, however, there was no statistically significant correlation between the enhancement change in the tumor and treatment response.

**Problems Using Gamma Knife Surgery in Focal Brainstem Tumors**

Before the introduction of MR imaging, biopsy procedures were routinely performed prior to initiating further treatment for brainstem tumors. Since the widespread use of MR imaging, the characteristics of the tumor as seen on MR images and the clinical course usually provide adequate information to enable the physician to diagnose a low-grade tumor. Daglioglu and colleagues reviewed the published series of 118 patients with tectal gliomas in the literature, who had histological data from either biopsy procedures or tumor resection. In these patients, there were 94 low-grade gliomas, 14 high-grade gliomas, and one case each of ependymoma, pineocytoma, and oligodendrogliomas. Seven of the biopsy specimens were inconclusive. In our series, 10 patients did not have histopathological data. The risk of using GKS without histopathological data would be treating patients who might have more benign lesions in the brainstem, such as gangliogliomas, dermoid/epidermoid cysts, or hemangioblastomas. However, these more benign lesions typically have different MR imaging characteristics (such as cyst formation and heterogeneous enhancement) and can be distinguished from low-grade gliomas. In addition, our policy is to restrict GKS to only those patients with progressing tumors or worsening neurological deficits.

**Surgical Complications**

A variety of postradiation reactions in the brain, which depend on the time course of GKS, are well described in the conventional radiotherapy literature. Similar reactions have also been observed in radiosurgical patient series.

Early reactions usually occur weeks to months after radiotherapy, are generally transient, and require no specific therapy. Although good evidence is lacking, temporary demyelination has been proposed as the underlying mechanism of these reactions. These reactions may be associated with exacerbation of preexisting deficits or the development of new symptoms. Marked somnolence and lethargy have been reported in children treated with whole-brain radiotherapy with a total dose as low as 24 Gy. The 7-year-old boy (Case 4) in our series experienced extrapyramidal symptoms and impaired consciousness 1 week after GKS. In this patient FLAIR imaging revealed high signal changes involving the fornices bilaterally. However, these changes could have been MR imaging artifacts and did not explain the clinical syndrome.

A low-intensity area surrounding the treated lesion that develops after radiosurgery has been reported in the literature, but the mechanism of this area is not yet clear. Occasionally, this change leads to transient neurological deterioration. In our patient series, a small low-intensity area surrounding the tumor on T1-weighted MR imaging was observed in eight patients. One of these patients presented with transient headache.

The nature of late radiation-induced changes in the brain as seen on MR imaging months to years after treatment remains to be elucidated. These changes presumably represent an array of pathological processes, ranging from gliosis to true necrosis. It is important to emphasize that the signal changes on MR images associated with clinical deterioration are too frequently interpreted as radionecrosis despite the fact that the changes are usually transitory. The tumor in one patient in our study (Case 8) became necrotic following GKS. The patient’s clinical condition deteriorated and he again required surgery. The necrotic tumor was able to be extirpated quickly and completely without trauma, which was not possible during two previous resection attempts. However, this observation still does not allow us...
to contend that radiosurgically induced necrosis of a tumor before surgery could be beneficial.

A few isolated cases of secondary tumor development after GKS have been reported. At the University of Virginia, we reviewed the cases of 1333 patients with AVMs treated using the Gamma Knife; 288 of the patients underwent follow-up imaging for at least 10 years. We observed meningioma formation in two patients with AVMs longer than 10 years after GKS; this translates to an incidence of radiosurgically induced neoplasia of 69 in 100,000 person-years.

Considering the long latency of tumor induction, however, this incidence rate is not inconsequential if one considers only those patients with long-term follow up. Continuous observation is prudent in these patients, particularly in the vulnerable young patients who are expected to have a long survival.

Conclusions

For intracranial glial tumors, survival following microsurgery has been correlated with the extent of resection. When tumors involve critical areas, safe maximum cytoreduction with acceptable morbidity should be the goal of treatment. Using GKS appears to be safe and effective for focal brainstem gliomas. Therefore, its use as an initial treatment before surgery could be beneficial.

References


C. P. Yen et al.
Gamma Knife surgery for brainstem gliomas


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