Evaluation of the role of Gamma Knife surgery in the treatment of craniopharyngiomas

Rupa Gopalan, B.S., Kasandra Dassoulas, B.S., Jessica Rainey, Jonathan H. Sherman, M.D., and Jason P. Sheehan, M.D., Ph.D.

Department of Neurological Surgery, University of Virginia Health System, Charlottesville, Virginia

The management of craniopharyngioma involves balancing adequate reduction in tumor volume and prevention of recurrence while minimizing damage to delicate surrounding structures. Because of the lesion’s proximity to the optic chiasm and its relationship to the hypothalamic–pituitary axis, morbidity rates following treatment can be high. Gamma Knife surgery (GKS) is now being considered as a viable method of providing tumor control while ensuring minimal side effects. The authors conducted a literature review of 10 studies in which GKS was used to treat craniopharyngioma; some lesions had been previously treated and some had not. The mean marginal dose ranged from 5 to 16.4 Gy (mean 12.3 Gy). Tumor control was achieved in 75% of cases overall and varied with tumor subtype (cystic, solid, mixed). Control was seen in 90% of solid, 80% of cystic, and 59% of mixed tumors. The overall morbidity rate resulting from radiosurgery was 4% and the overall mortality rate was 0.5%. These results suggest that GKS may provide a favorable benefit-to-risk profile for many patients with craniopharyngiomas.

(DOI: 10.3171/FOC/2008/24/5/E5)

Key Words • craniopharyngiomas • Gamma Knife • radiosurgery

Cranopharyngiomas are tumors of the parasellar region that arise from residual epithelial cells of the Rathke pouch. They may be solid, cystic, or mixed in nature and are commonly calcified. Up to 60% of cranopharyngiomas have both cystic and solid components.\(^7\)\(^,\)\(^28\) Cranioopharyngiomas occur in a bimodal age distribution, generally appearing in young patients between the ages of 5 and 14 years and in older patients between 50 and 74 years. According to an international meta-analysis of \(\geq\) 10,000 individuals, cranioopharyngiomas account for \(\sim\) 7.8% of pediatric brain tumors.\(^31\) Because the tumor is relatively rare and generally benign, the results of demographic studies in adults are inconclusive.

Although histologically benign, the resulting clinical sequelae can be severe. Neurological symptoms can be divided into those resulting from mass effect and those resulting from dysfunction of the hypothalamic–pituitary axis. Mass effect can result in increased intracranial pressure presenting as headache, nausea, and vomiting. Obstruction of the aqueduct of Sylvius or the foramina of Monro may result in hydrocephalus in cases with large mass lesions.\(^10\) Hydrocephalus is a more common presenting sign in children than in adults.\(^15\) Due to its location in the sellar and parasellar areas, compression of the optic chiasm typically results in bitemporal hemianopsia. Visual disturbance can also include central visual defects, optic atrophy, and papilledema. Headache and visual field defects are the most common presenting symptoms.\(^2,\)\(^18,\)\(^20\) Endocrine disruption is often suppressed, manifesting as amenorrhea, hypothyroidism, orthostatic hypotension, and diabetes insipidus, which occurs in as many as 15% of cranioopharyngioma patients.\(^8,\)\(^15\) In children, growth hormone deficiency may result in delayed puberty and short stature.\(^1,\)\(^22\)

Treatment options for cranioopharyngioma include total or subtotal resection, external-beam radiation therapy, stereotactic radiation therapy, intracavitary irradiation, or a combination of treatment modalities. More recently, GKS has been utilized as either a primary or secondary treatment for cranioopharyngioma patients. Given the spectrum of treatments available for this tumor, proper management remains controversial. In this paper, we evaluate the current role of Gamma Knife radiosurgery in the neurosurgical treatment armamentarium for cranioopharyngioma patients.

Clinical Materials and Methods

In this study we review the trends in treatment of cranioopharyngiomas for both pediatric and adult populations. Ten major studies of outcomes after GKS for cranioopharyngioma were evaluated. Case studies were not included. Studies were evaluated for age at presentation, prior resection, concurrent treatment with intracavitary irradiation or bleomycin, follow-up duration, marginal radiation, mortality and morbidity rates, tumor control, and tumor progression (Table 1).

Results

Population Characteristics

The patient populations each ranged from 5 to 98 cases...
<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Study Period</th>
<th>No. of Patients/ Tumors</th>
<th>Mean Age (yrs)</th>
<th>Prior Tumor Resection</th>
<th>Mean Value</th>
<th>Treatment (%)</th>
<th>Intracavitary Isotope</th>
<th>Bleomycin</th>
<th>Follow-Up (yrs)</th>
<th>Marginal Dose (Gy)</th>
<th>Tumor Size (cm³)</th>
<th>Tumor Control Rate (%)</th>
<th>Tumor Progression Rate (%)</th>
<th>Further Treatment Rates (%)</th>
<th>Adjuvant Resection</th>
<th>Morbidity</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kobayashi et al., 2005</td>
<td>1993-2005</td>
<td>98/60</td>
<td>38 &lt; 15</td>
<td>60 &gt; 15</td>
<td>31/32</td>
<td>74</td>
<td>6.5</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>5.5</td>
<td>3</td>
<td>11.5</td>
<td>3.5</td>
<td>93</td>
<td>79</td>
</tr>
<tr>
<td>Chung et al., 2000</td>
<td>1993-1999</td>
<td>21/11</td>
<td>11 &lt; 15</td>
<td>10 &gt; 15</td>
<td>21/22</td>
<td>56</td>
<td>19</td>
<td>23</td>
<td>0</td>
<td>13.6</td>
<td>8</td>
<td>5</td>
<td>100</td>
<td>100</td>
<td>75</td>
<td>87.2</td>
<td>12.8</td>
</tr>
<tr>
<td>Ulfarsson et al., 2002</td>
<td>1992-1998</td>
<td>21/11</td>
<td>15</td>
<td>56</td>
<td>15</td>
<td>43</td>
<td>4</td>
<td>2</td>
<td>7.8</td>
<td>7</td>
<td>3</td>
<td>26</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Mokry et al., 2002</td>
<td>1996-2001</td>
<td>7</td>
<td>NA</td>
<td>100</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>4.2</td>
<td>14.2</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>100</td>
<td>0</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Barua et al., 2003</td>
<td>1998-2001</td>
<td>10/8</td>
<td>14.5</td>
<td>50</td>
<td>30</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>5.65</td>
<td>16.4</td>
<td>1.74</td>
<td>100</td>
<td>37.5</td>
<td>58</td>
<td>42</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Chiou et al., 2001</td>
<td>1998-2001</td>
<td>12</td>
<td>38.1</td>
<td>67</td>
<td>44</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>NA</td>
<td>12.9</td>
<td>0</td>
<td>100</td>
<td>30</td>
<td>62.5</td>
<td>37.5</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>Prasad et al., 1995</td>
<td>1994-2000</td>
<td>14</td>
<td>11.5</td>
<td>86</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.3</td>
<td>14</td>
<td>3.7</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>86</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Amendola et al., 2003</td>
<td>1983-2005</td>
<td>5</td>
<td>13</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2.4</td>
<td>NA</td>
<td>6.5</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>86</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Albright et al., 2005</td>
<td>1996-1999</td>
<td>46</td>
<td>39</td>
<td>61</td>
<td>72</td>
<td>6.5</td>
<td>0</td>
<td>0</td>
<td>1.33</td>
<td>8-18</td>
<td>13.5</td>
<td>90</td>
<td>86</td>
<td>89</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* Cyst = cystic-type tumor; mix = mixed-type tumor; NA = not available; Prog = progression; sol = solid-type tumor; — = none.
† Not included in overall evaluation of morbidity due to ambiguity in the cause of new symptoms and the effects of concurrent surgical manipulation.
‡ Study provided only the range of values.
Radiosurgery for craniopharyngiomas

and included both children and adults. The average age of patients was 25.6 years (range 13–39 mean age). In 2 studies, tumor outcome was evaluated based on the number of tumors, as opposed to the number of patients. Kobayashi et al.19 and Ulfarson et al.26 did not report mean age, but patients > 15 years of age comprised 61 and 48% of these respective studies. Of the 10 studies reporting follow-up durations, the mean follow-up time was 4.6 years (range 1.33–13.6).

Treatment Prior to GKS

On average, in 63% (range 0–100%) of cases, prior resection had been performed (either subtotal or complete). An average of 29% of patients underwent intracavitary radiotherapy prior to GKS. Patients in 2 studies were treated with bleomycin prior to GKS, 3% in the study by Kobayashi et al.19 and 43% in the study by Mokry.27

Radiosurgical Dose

On average, the mean marginal dose was 12.3 Gy (range 5–16.4 Gv). Mokry27 reported a mean marginal dose of 7.8–9.7 Gv, and Yu et al.28 reported a range of doses from 8–18 Gv (mean dose not available).

Tumor Control and Progression

All studies defined tumor control as a stable or decreased size of the tumor following GKS. Preoperative tumor sizes ranged from 1.74 to 13.5 cm³ (mean 7 cm³) and the mean size was not reported in 1 study. The mean tumor control rate was 75% (range 36–100%). Solid tumors were treated in 6 studies and their mean control rate was 90% (range 57–100%); cystic tumors were treated in 4 studies and their mean control rate was 88% (range 74–100%); and mixed tumors were treated in 7 studies and their mean control rate was 58.6% (range 21–86%). Tumor progression was observed in ~ 25% of cases (range 0–67%).

Further Treatment After GKS

An average of 4% of patients underwent intracavitary radiotherapy following GKS. Chung et al.8 and Mokry27 treated patients with bleomycin following GKS to control cysts in 3 and 4% of patients, respectively. An average of 4% of patients (range 0–22%) required an additional resection in an attempt to control tumor progression. An average of 7% of patients (range 0–14%) underwent an additional treatment with GKS.

Morbidity and Mortality Rates

Assessment of morbidity included both endocrinological and visual deterioration resulting from GKS. Overall morbidity rates were low at 4% (range 0–19%). Death was only observed in 1 study and was reported as 5% of the population, giving an average mortality rate of 0.5% across all 10 studies. In 50% of the studies investigators reported no morbidity or mortality associated with GKS. Barua et al.3 reported a high incidence of morbidity, but this series was omitted from tabulation due to ambiguity in the underlying cause of the complications.
10–50% of cases. Although the utility of radiosurgery in treating craniopharyngiomas is still being analyzed in comparison to GTR, some studies have suggested that GTR is most strongly recommended in cases lacking hypothalamic involvement, whereas adjunctive or primary radiosurgery should be considered in other cases to decrease the rates of postoperative morbidity and mortality.1

Inoue et al.14 observed that GTR for craniopharyngioma causes more hypothyroidism during the 2 weeks postoperatively and that radiosurgery-treated patients may have preserved function without the need for hormone replacement postoperatively. In a pediatric series of 66 patients, growth hormone deficiency was documented in 100% of cases, gonadotropin deficiency in 80%, and hypothyroidism in 74% following either gross-total or partial craniopharyngioma resection.11 Radiotherapy following surgery did not increase the incidence of endocrine abnormalities, suggesting that the most of dysfunction following craniopharyngioma management results from surgery itself.

Forms of Adjunctive Radiotherapy

Several options exist for cases not amenable to GTR. Subtotal resection may be followed by conventional radiotherapy, intracavitary irradiation, fractionated radiotherapy, and stereotactic radiosurgery. Radiotherapeutic techniques have also been performed as a primary treatment modality in patients with no history of resection.

Fractionated Stereotactic Radiotherapy. Fractionated stereotactic radiotherapy delivers conventionally fractionated radiation with some degree of precision, and it has been suggested to provide increased tumor control with lower toxicity. It involves the use of computed tomography and/or magnetic resonance imaging for treatment planning. The delivery of radiation is more localized than that achieved with conventional radiotherapy. A 5-year progression-free survival rate of 92% has been reported for fractionated stereotactic radiosurgery compared with 80–90% for complete excision and only 50–60% for partial resection.26 Despite its utility, fractionated stereotactic radiotherapy is still susceptible to several complications including vasculitis, neuropsychological changes, worsening of visual symptoms, and, rarely, an increased occurrence of secondary tumors.1

Stereotactic Intracavitary Irradiation. Stereotactic intracavitary radiation with yttrium-90 or phosphorus-32 beta-emitting isotopes has been widely shown to be an effective primary treatment for multicystic or medium-sized monocystic tumors12,22 but not useful for solid tumors.12 This type of therapeutic approach has been shown to control up to 96% of cystic tumors23 and 88% when including all forms of partially cystic tumors.29 Side effects include blindness, CN dysfunction, new-onset diabetes insipidus,29 and panhypopituitarism.12,37 Vision may improve (48%) in some patients but can deteriorate in others (29%) following treatment.12 An additional limitation is the progression of solid elements or secondary cyst formation, requiring further treatment.23

Primary or Secondary GKS as a Treatment for Craniopharyngioma

Gamma Knife surgery involves stereotactic neuroimag-
dysfunction resulting in changes in sleep and appetite, endocrine changes, visual defects, radiation necrosis, and malignant lesions. Complications resulting from radiation therapy vary depending on patient age, tumor size, and radiation doses. However, several authors have found that GKS provides excellent tumor control with minimal or no postoperative morbidity or mortality. 

Risk associated with GKS is elevated when a large cystic volume obscures the visibility of other structures, such as visual pathways, or if there is tumor adherence to radiosensitive structures. Numerous authors have suggested the use of multimodal treatments in such cases because large cystic or mixed-type tumors can be reduced through cyst aspiration. Such volume reduction may reduce the risk of radiation-induced injury and allow more effective targeting of the solid portion of the tumor. Proper dose planning and avoidance of optic pathways becomes possible. In addition, an immediate improvement in a patient's condition can occur following aspiration of a cystic-type tumor, as compression of critical neural structures is relieved.

Conclusions

Gamma Knife surgery provides reasonable benefit-to-risk profile in the treatment of craniopharyngioma. In comparison to craniopharyngioma treated with resection alone, GKS appears to be associated with a decreased rate of morbidity and mortality. Due to great precision in tumor targeting, GKS may also be associated with fewer complications than other forms of radiation delivery. It can be used to treat residual or recurrent craniopharyngiomas after extirpation; it can also be used as an initial treatment option for some patients. Further studies will help to elucidate the role of GKS in the long-term management of craniopharyngioma in patients.

References


Accepted February 14, 2008.
Address correspondence to: Jason Sheehan, M.D., Ph.D., Department of Neurological Surgery, Box 800–212 University of Virginia Health System, Charlottesville, Virginia 22908. email: jps2f@virginia.edu.