Gross Total Removal of Gliomas in the Pulvinar and Correlative Microsurgical Anatomy

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Abstract

Tumors in the pulvinar tend to present as circumscribed lesions with exophytic growth into the lateral and third ventricles. These lesions may be best explored via a parietal-transcortical-transventricular approach. If the tumor extends posteriorly or inferiorly, a posterior-interhemispheric-transtentorial approach may provide a good angle of access. Gross total removal of the tumors in the pulvinar of two patients was achieved by surgical sectioning of the unilateral crus of the fornix or the splenium via a transventricular or interhemispheric approach with acceptable risk. These patients are now doing well as students about 6 years following the first operations. During tumor removal, a posterior-interhemispheric-transtentorial approach combined with above-mentioned approaches was useful for orientation of the critical structures in the posterior incisural space. Knowledge of the anatomical relationships of the pulvinar to the crus of the fornix and the choroid plexus, and to the critical structures located in the posterior incisural space is extremely important for neurosurgeons.

Key words: glioma, thalamus, pulvinar, microsurgery, microsurgical anatomy, surgical approach

Introduction

Thalamic gliomas account for about 1% of all central nervous system neoplasms. These tumors have a bimodal age distribution, with the incidence being highest among children and adolescents, and in adults over 40 years old. Unfortunately, little is known of the precise nature of these lesions due to a lack of histological verification in many published series. However, stereotactic biopsies of 44 cases showed that the majority of young patients harbored low-grade malignancy glial neoplasms (68.7%), whereas a large number of adult patients presented with high-grade malignancy glioblastomas (78.6%).13) The prognosis for patients with thalamic gliomas is critically dependent on the location and biological growth characteristics of the tumor. Tumors in this area can present as either diffuse or circumscribed lesions. Circumscribed lesions are indicated for microsurgical removal, because of the common location in the superior-anterior region of the thalamus, or posteriorly within the pulvinar. Such lesions also tend to grow exophytically into the lateral and third ventricles and are best explored via a transventricular approach. Pulvinar tumor sometimes extends posteriorly or inferiorly displacing the midbrain, and involves the ipsilateral half of the quadrigeminal and ambient cisterns, so the occipital transtentorial approach may provide a good angle of access.

The present study investigated the microsurgical anatomy along these approaches in the cadaver brain and describes two cases of pulvinar gliomas treated by gross total resection via several approaches.

Microsurgical Anatomy

Around the Pulvinar

The thalamus is an obliquely-oriented ovoid nuclear mass about 4 cm long. A posterior expansion is directed dorsolaterally, and overhangs the ipsilateral superior colliculus. This expanded posterior pole is the pulvinar (Figs. 1 and 2). Approach of the pulvinar and surroundings requires knowledge of the anatomical relationships of the pulvinar to the ventricles, fornix, choroid plexus, cisterns, and vessels.

The occipital view of the coronal section through the splenium of the corpus callosum on the right, with the tentorium preserved, shows the pulvinar is still covered by the incised isthmus of the cingulate
Fig. 1  Lateral (A) and posterolateral (B) views of the medial surface of a sagittal section through the midline with the brain stem sectioned at the level of the superior colliculus (6). The vessels, arachnoid membrane, dura mater, and choroid plexus have been removed. The anatomical relationships of the pulvinar (1) to the crus of the fornix (3), fimbria of hippocampus (2), pineal body (5), and superior colliculus can be clearly seen. 4: body of fornix, 7: splenium of corpus callosum, 8: septum pellucidum, 9: lateral ventricle, 10: foramen of Monro, 11: massa intermedia, 12: striae medullaris thalami, 13: isthmus of cingulate gyrus, 14: parahippocampal gyrus, 15: uncus, 16: peduncle, 17: medial geniculate body.

Fig. 2  Posterior (A) and posterosuperior (B) views of the anatomical relationships of the pulvinar (1) to the crus of the fornix (2) and the superior (4) and inferior (5) colliculi. The splenium and pineal body have been removed. 3: hippocampal commissure, 6: peduncle, 7: medial geniculate body, 8: third ventricle, 9: internal cerebral vein, 10: lateral ventricle, 11: choroid plexus.

gyrus and lingual gyrus (Fig. 3A). The trigone of the lateral ventricle is opened and the glomus of the choroid plexus is also exposed.

A section extended slightly forward to the level of the posterior limit of the parahippocampal gyrus, with the splenium of the corpus callosum divided in the midline, shows the radiation of the corpus callosum is sectioned, but the fimbria or alveus of the hippocampus is not (Fig. 3B).

The fornix, consisting mostly of efferent fibers from the hippocampal formation, begins as fibers that collect on the ventricular surface of the hippocampus as the alveus. The fibers run medially to form the fimbria of the hippocampus, then part form the hippocampal formation near the splenium to become the crus of the fornix (Figs. 1, 2B, and 3C). The two crura converge on the midline, forming the body of the fornix. At this location, fibers are exchanged between the two crura in the hippocampal commissure (Fig. 2).

A section extended slightly more anteriorly shows the crus of the fornix broadens as if wrapped around
the posterior margin of the pulvinar (Fig. 3D, E). The pulvinar is now exposed in the posterior incisural space and the trigone of the lateral ventricle. Surgically, the pulvinar is reached from above through the crus of the fornix transventricularly (Fig. 4A) or from posteriorly through the unilateral posterior incisural space (Fig. 3D). The choroidal fissure located between the fornix and the thalamus is the site of attachment of the choroid plexus in the lateral ventricle (Fig. 3D–F). The pineal body is located in the midline, between the bilateral pulvinars, which overhang the superior colliculi (Fig. 3E, F).

The posterior cerebral artery runs through the lateral part of the posterior incisural space and bifurcates into the calcarine and parietooccipital arteries. The medial posterior choroidal arteries enter the posterior incisural space anteriorly, turn forward beside the pineal body, and enter the velum interpositum (Fig. 3D). The lateral posterior choroidal arteries arise in the posterior incisural space, and pass around the posteromedial surface of the pulvinar and then through the choroidal fissure to supply the choroid plexus in the trigone and pulvinar (Fig. 4D). The superior choroidal veins, which run
on the surface of the choroid plexus, and the direct lateral veins enter the internal cerebral vein (Fig. 4). The basal vein of Rosenthal, passing around the midbrain (ambient cistern) just adjacent to the posteromedial surface of the pulvinar, and the internal cerebral veins, exiting the velum interpositum, converge to form the vein of Galen behind the pineal body (Figs. 3F and 4D). The arachnoid membrane over the vein of Galen group is tough and opaque, and is resected.

Resection of the tentorium exposes the superior surface of the cerebellum and clearly visualizes the branches of the superior cerebellar artery (Fig. 3D). This procedure provides an excellent view around the tentorial edge, especially below the tentorium, and of the ambient cistern.32)

**Surgical Approaches to the Pulvinar**

Tumors in the pulvinar may be approached 1) from above the tentorium using a parietal-transcortical-transventricular approach,38,39,42) 2) through the posterior part of the lateral ventricle using a posterior-interhemispheric-parasplenial-transventricular approach,40) 3) through the corpus callosum using a posterior-interhemispheric-transcallosal approach,1,10) 4) along the medial surface of the occipital lobe using a posterior-interhemispheric-transventricular approach,23,34) or 5) from below the tentorium through the supracerebellar space using an infratentorial-supracerebellar approach.38)

**Parietal-transcortical-transventricular approach:** The cortical incision is made along the superior parietal lobule. Once inside the trigone of the lateral ventricle, the choroid plexus and the crus of the fornix overlying the tumor are visualized and may have to be removed and/or incised to gain access to the lesion.

**Posterior-interhemispheric-parasplenial-transventricular approach:** The parietooccipital lobe is retracted away from the falx and interhemispheric dissection is performed. The cortical incision is made along the posterior part of the precuneus (anterior to the parietooccipital sulcus) and the trigone is entered as in the previous approach.

**Posterior-interhemispheric-transcallosal approach:** After posterior interhemispheric dissection is performed, as in the previous approach, the splenium of the corpus callosum is incised to gain access into the trigone. This approach provides access to the roof and medial part of the trigone.

**Posterior-interhemispheric-transventricular approach:** The corona radiata is divided in the midline. The radiation of the corpus callosum is then sectioned.2
**Fig. 4** A: Superior view of the trigone of the right lateral ventricle. The crus of the fornix (1) overlying the pulvinar is incised at the level of the splenium (2). The direct lateral vein (3) coursing medially across the pulvinar is visualized. The medial wall of the trigone of the lateral ventricle is retracted by a spatula (6). 3: choroid plexus, 4: superior choroidal vein. B: Superior view of a horizontal section through the level of the splenium of the corpus callosum (5) and the habenula (2). The third ventricle (1) is exposed, and the bilateral internal cerebral veins (9) and the vein of Galen (10) are sectioned. 3: pulvinar, 4: posterior limb of internal capsule, 6: retrosplenial gyrus, 7: choroid plexus of lateral ventricle, 8: choroidal fissure, 11: fornix. C: Superior view of the same section as in Fig. 4B. The splenium of the corpus callosum has been removed to expose the tela choroidea (4). 1: third ventricle, 2: habenula, 3: pulvinar, 5: direct lateral vein, 6: fimbria of hippocampus. D: Superior view of the same section as in Fig. 4B and C, showing the relationships of the pulvinar (1) to the deep venous system and the medial posterior choroidal artery (9) after removal of the tela choroidea. 2: pineal body, 3: superior colliculus, 4: direct lateral vein, 5: internal occipital vein, 6: basal vein of Rosenthal, 7: internal cerebral vein, 8: vein of Galen, 10: lateral posterior choroidal artery, 11: posterior cerebral artery, 12: vermian branch of superior cerebellar artery.

**proach**: After interhemispheric dissection is performed, the tentorium is cut and the thick arachnoid around the ipsilateral basal vein of Galen group is divided. The occipital lobe is retracted away more laterally to visualize the posteromedial surface of the pulvinar. The splenium is gently retracted upward to allow for extra-exposure.

**Infratentorial-supracerebellar approach**: Inferior retraction is placed on the vermis of the cerebellum. After the thick arachnoid membrane is divided, the precentral cerebellar vein is sacrificed to gain access to the pulvinar in the posterior incisural space from the contralateral side.

**Case Presentation**

**Case 1**: A 15-year-old, right-handed girl was admitted with a 2-day history of headache and nausea. Her illness had started 2 weeks earlier, with mild hyposthesia of the left side of the body. Neurological...
Fig. 5 Case 1. A: Preoperative magnetic resonance (MR) image with contrast medium (left) showing an enhanced mass with a cystic component, originating from the right pulvinar with some enlargement of the lateral ventricles (Fig. 5A left). The tumor was treated via a right parietal-transcortical-transventricular approach in November 1996. A parietal craniotomy was performed with the patient in the supine position. A cortical incision was made along the superior parietal lobule. Entry into the trigone of the lateral ventricle found the tumor was covered by the extended crus of the fornix, which was incised in the direction of the fibers. Biopsy of the tumor found a benign glioma. Decompression was readily accomplished because a large cyst was present ventrally and the border was clear enough to resect the tumor subtotally. Some of the tumor was attached to the well-developed direct lateral vein and was not resected. An Ommaya’s reservoir was placed in the surgical cavity. The postoperative course was uneventful, with no memory disturbance or aphasia. The histological diagnosis was pilocytic astrocytoma. Postoperative MR imaging confirmed the subtotal removal of the tumor (Fig. 5A right). No additional radiotherapy or chemotherapy was performed.

MR imaging revealed that the right thalamic tumor had increased in size with a cystic component, without worsening of neurological signs in April 1999, when the patient was 18 years old. She underwent γ-knife radiosurgery and chemotherapy with 1-(4-amino-2-methyl-5-pyrimidinyl)methyl-3-(2-chloroethyl)-3-nitrosourea hydrochloride (ACNU) and interferon-β (IFN-β). However, serial MR imaging showed slow tumor progression (Fig. 5B). We reoperated with standard microneurosurgical techniques in December 1999, approaching the tumor through both the same approach as in the prior operation and a posterior-interhemispheric-transtentorial approach. The latter approach provided a better angle of access to the lesion extending into the quadrigeminal and ambient cisterns, and displacing the midbrain. The recurrent tumor, which was also a pilocytic astrocytoma without malignant changes, was totally resected. The patient had no new neurological deficit postoperatively and was discharged 10 days later. She was treated with chemotherapy using ACNU and IFN-β. Her condition has been stable during the 2.5 years since the second operation (5.5 years since the first operation). She is doing well as a college student without any evidence of tumor on MR imaging (Fig. 5C).

Case 2: A 12-year-old, right-handed boy was admitted with a 4-day history of headache and vomiting. His illness had started a month earlier, with diplopia. Neurological examination revealed upward
Fig. 6 Case 2. A: Preoperative magnetic resonance (MR) images with contrast medium showing an enhanced mass with cystic components, originating from the right pulvinar. B: Follow-up MR images with contrast medium 2 months after the first operation showing the cystic part of the tumor has increased in size. C: MR images with contrast medium 6 years following the first operation. The tumor was totally resected.

Discussion

I. Surgical approaches to gliomas in the pulvinar

Historically, attempts at resection of thalamic tumors have lead to disastrous surgical morbidity and mortality. Surgical therapy for thalamic tumors has evolved from initiation of radiation therapy without prior histological diagnosis to open biopsy for histological diagnosis to select the appropriate therapy and, more recently, CT-guided stereotactic biopsy. The latest method for the resection of thalamic tumors is based on computer-assisted stereotactic microsurgical technique or computer- and robot-assisted techniques. However, the unsolved problem of brain shift during the course of surgery has been recognized as a limiting factor for radical resection based on preoperative imaging.

Efforts to preserve neurological function will result in incomplete resections because of anatomical limitations or malignant histology. On the other hand, improved understanding of the growth pat-
terns and locations of the tumors much reduced perioperative mortality, and increased efficacy of adjuvant therapeutic strategies have lead to a more aggressive approach to these lesions. Radical or maximum removal of thalamic gliomas has been recently reported using an operating microscope with acceptable morbidity via several routes. Circumscribed and histologically benign lesions may be considered favorable for microsurgical removal. Tumors of the pulvinar, in particular, tend to grow exophytically into the lateral and third ventricles, and sometimes extend posteriorly or inferiorly into the quadrigeminal and ambient cisterns (ipsilateral half of the posterior incisural space). The former type is best explored via a transventricular approach and the latter type is best explored via an occipital-interhemispheric-transventricular approach. In our patients, we used several approaches from a strategic point of view. For Case 1, a parietal-transcortical-transventricular approach was used for the subtotal removal in the first operation and a transventricular approach was added for the gross total removal in the second operation. For Case 2, a posterior-interhemispheric-parasplenial-transventricular approach was used for the partial removal in the first operation, and a posterior-interhemispheric-transsplenial approach, combined with a transtentorial approach, was used for the gross total removal in the second and third operations.

A parietal-transcortical approach may be suitable from the anatomical point of view for most tumors of the pulvinar. However, if the tumor extends posteriorly or inferiorly into the quadrigeminal and ambient cisterns, resulting in displacement of the midbrain, another approach should be added. A posterior-interhemispheric-transventricular approach is useful to provide a better angle of access for this lesion. However, to expose the posteromedial surface of the pulvinar, the occipital lobe should be retracted more laterally and more extensively. In some cases, such as our Case 2, a posterior-interhemispheric-transcallosal approach should be chosen if the tumor extends medially under the corpus callosum.

A modification of an infratentorial supracerebellar approach was chosen to treat a small tumor. A paramedian approach from the contralateral side was developed to center the pulvinar within the limited field of access between the basal veins of Rosenthal of both sides. However, this route is restricted to partial removal and is not suitable for maximum surgical removal because sacrifice and manipulation of the deep venous system as well as dissection in the quadrigeminal cistern may result in critical neurological deficits.

II. Surgical approaches and morbidity

There are several important structures which the surgeon is obliged to sacrifice when approaching the pulvinar, such as the crus of the fornix, the splenium of the corpus callosum, and the optic radiation. One of our patients underwent surgical sectioning of the unilateral crus of the fornix, the hippocampal commissure, and the splenium, and the other underwent sectioning of the unilateral crus of the fornix only, but neither manifested any of the signs of callosal disconnection or amnesia on bedside examination including the Mini-Mental State Examination and examinations for disconnection syndrome, or any of the signs of homonymous hemianopsia.

Sectioning of the crus of the fornix: A posterior-transventricular approach provides adequate exposure of the trigone and posterior portion of the lateral ventricle. The incision through the fornix should be carried out on the same side as the procedure if using this approach to expose the posterior thalamus or pulvinar. There is no agreement whether fornix integrity is required for normal memory. Unilateral fornix sectioning may not cause any evidence of memory disturbance. However, even an unilateral lesion may produce transient or permanent amnesia. Bilateral fornix sectioning has been implicated in causing memory disturbance, although memory disturbance has not occurred even with bilateral fornix sectioning. Previous cases of the thalamic glioma have shown more or less uniform displacement of the crus of the fornix on the affected side, associated with thinning or infiltration by the tumor growth. The crus of the fornix was not even identifiable consistently, although there were no apparent memory deficits in any case. The risk of morbidity caused by sectioning the crus of the fornix in the parietal-transcortical-transventricular approach can be avoided by approaching through the choroidal fissure between the crus of the fornix and the thalamus. However, larger tumors extending postero-medially into the posterior incisural space as in the present cases, may be hard to approach through the choroidal fissure without injuring the crus of the fornix. Sectioning of the splenium of the corpus callosum may also divide the hippocampal commissure. A number of efferent fibers of the crus of the fornix decussate to the opposite side and form the hippocampal commissure under the splenium of the corpus callosum. This commissure should be preserved to prevent major memory loss.

Sectioning of the splenium of the corpus callosum: Partial sectioning of the corpus callosum to facilitate the operative approach to deep midline
lesions may produce only components of the full syndrome, depending on the part of the corpus callosum that was cut as well as on the amount and nature of any associated extracallosal damage. The posterior portion or splenium of the corpus callosum is incised to enter the lateral ventricle and thus has been associated with a disconnection syndrome. Sectioning of this portion, where more visual information crosses, commonly causes left hemialexia and color anomia.\textsuperscript{6,9,17,22,44} If only a small incision of the displaced and thinned splenium is required, as in our Case 2, such symptoms might not occur.

**Injury to the optic radiation:** Transcortical approaches can result in direct injury to the optic radiation, causing homonymous hemianopsia, so should be avoided. When using a posterior-interhemispheric-transsplenial-transventricular approach, an incision is made along the parasplenial cortices including the precuneus (anterior to the parietooccipital sulcus) to preserve the integrity of the optic radiation.\textsuperscript{60} When using a parietal-transcortical-transventricular approach, homonymous hemianopsia may occur if the cortical incision of the superior parietal lobe is made too posteriorly or excessive retraction is employed. When using a posterior-interhemispheric-transtentorial approach, sacrifice of bridging veins from the occipital lobe may cause venous infarction with subsequent visual deficit. Sacrifice of the internal occipital vein, although usually not causing any deficit, may be associated with homonymous hemianopsia due to excessive retraction of the occipital lobe.\textsuperscript{19}

Generally speaking, patients with thalamic tumors have a poor prognosis despite aggressive chemotherapy and radiation therapy regimens. Although the benefits of maximum or radical surgery are yet unproven, we believe that surgical therapy is justified if the tumor is well circumscribed and shows exophytic growth into the lateral and third ventricles, because the morbidity and mortality are acceptable. No complications were detected in our two patients, and they are doing well as students in a college and a high school, respectively, with no memory loss or cognitive dysfunction.

**III. Conclusion**

Gross total removal of pulvinar glioma is possible with surgical sectioning of the unilateral crus of the fornix or the splenium via a transventricular or interhemispheric approach with acceptable risk. A posterior-interhemispheric-transtentorial approach, combined with another approach, is useful for orientation of the critical structures in the posterior incisural space.

**References**


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Commentary
In the past, resection of thalamic tumors has led to catastrophic surgical results due to the site of the tumor and injury to the surrounding anatomic structures. In reviewing the related microsurgical anatomy around the pulvinar and the surgical approaches to the pulvinar, the authors reported two cases of pulvinar glioma with gross total removal and encouraging surgical results. It is good that the authors discuss in detail the three different surgical approaches and their morbidities, i.e. sectioning of the crus of the fornix, of the splenium of the corpus callosum, and of the paraspellial cortices. The authors confirmed the findings of other studies that circumscribed pulvinar gliomas tend to grow exophytically into the lateral and third ventricles or extend posteriorly or inferiorly into the quadrigeminal and ambient cisterns. The former type is best explored via a transventricular approach

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and the latter type is best explored via an occipital-interhemispheric-transtentorial approach. In both cases, the tumor was subtotally or partially resected in the first operation, and gross totally removed in the second and third operations (Case 2) with ingenious selection of suitable approaches according to the location and size of the tumor without memory loss or cognitive dysfunction. The patients are now doing well as students, one is in college and the other in high school. This surgical strategy deserves recommendation. I would suggest, if possible, open MRI guided (or assisted) microsurgery for resection of this deep seated tumor, which will make the surgery more safe. Anyway, all I can do is to congratulate the authors on doing excellent work for these two challenging patients.

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The authors report 2 patients with gliomas in the pulvinar who were successfully treated by gross total tumor removal. They also detail the microsurgical anatomy correlated with their surgical approaches. At present, it remains an open question whether attempted radical resection of infiltrating tumors located centrally within the basal ganglia improves the generally poor outcomes. As the authors indicated, thalamic astrocytomas have a tendency for exophytic growth into the lateral and third ventricles and total or subtotal removal is thought to be one of the principal positive prognostic factors for the survival of patients with thalamic astrocytomas. Regarding this point, I think that the authors have made a very useful contribution to the subject of microsurgical approaches to thalamic pulvinar tumors. In patients with grade 3 gliomas, the expected survival after gross total removal and adjuvant radio-chemotherapy is 5 years at most. I am amazed that their patient with anaplastic glioma (Case 2) survived for more than 6 years. On the other hand, pilocytic astrocytomas can be removed completely and patients tend to have a good outcome provided that they receive appropriate postoperative chemotherapy. In cases with invasion of the tumor into critical structures, aggressive removal should be avoided.

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In their article, Ryoji Ishii and co-workers have described the correlative microsurgical anatomy of the pulvinar region in two clinical cases treated for gliomas of the pulvinar thalami. The authors underline the importance of precise knowledge of the anatomical relationships of the thalamus in operating on deep seated pulvinar lesions. The anatomical description of the region is very accurate, but it would have been beneficial to present material and methods in the experimental part of the article. The surgical approaches to the pulvinar region were discussed from an anatomical point of view, such as the parietal-transcortical-transventricular, the posterior-interhemispheric-parasplenial-transventricular, the posterior-interhemispheric-transcallosal, the posterior-interhemispheric-transtentorial, and the infratentorial-supracerebellar approaches. The authors used the parietal-transcortical-transventricular and the posterior-interhemispheric-parasplenial-transventricular approaches in two young patients with a pilocytic astrocytoma and an anaplastic glioma. In both cases, despite sectioning of the crus fornicis, the lesions could not be removed totally, the residual tumors were treated using radiotherapy and chemotherapy. Because of enlargement of the residual tumors, reoperations were necessary, allowing total resection. In our institution we use very different approaches for approaching the pulvinar thalami, according to the individual patho-anatomical situation. We use the transcortical-transventricular approach for tumors growing superiorly into the ventricular chamber, the posterior subtemporal approach for lesions extending laterally into the ambient cistern, and the posterior interhemispheric subcallosal or the contralateral infratentorial supracerebellar approaches for lesions extending posteriorly into the quadrigeminal region. The goal of approach-planning should be to achieve a minimal invasive and maximal effective exposure, allowing total tumor removal without injury of eloquent structures not related to the lesion.

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