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Astrocytomas of the cerebral peduncle in children: surgical experience in seven patients

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Abstract *Objects:* Cerebral peduncle tumors are rare in childhood but often consist of benign astrocytomas. Surgical resection, however, is considered to be detrimental because of the highly sensitive neural structures. These tumors are often treated by radiation therapy (RT). We resected such tumors in seven patients, whom we then followed up without adjuvant therapy. The surgical approach and postoperative course are analyzed. *Methods*: Seven children, ranging in age from 4 to 16 years, were treated from 1993 to 2000. Tumors showed extension in various directions to the thalamus, pons and neighboring cisterns. All were treated by surgical resection through a subtemporal approach: total resection was achieved in three and subtotal resection in four. Operative complications were minimal. Two patients were worse after surgery, albeit temporarily, in motor, oculomotor or memory functions. All the tumors were benign astrocytomas. None of the patients received postoperative RT. Only one patient had a recurrence during the follow-up period, which ranged from 1 year to 8.5 years in duration. *Conclusions:* Benign astrocytomas of the cerebral peduncle are amenable to radical tumor resection by an appropriate surgical approach and with microsurgical techniques. Even following subtotal resection, these tumors frequently remain stable or involute. These children can be spared RT.

Keywords Brain stem · Midbrain · Brain neoplasm · Cerebellar peduncle · Astrocytoma

Introduction

Tumors of the brain stem are relatively common, accounting for approximately 10–15% of all brain tumors in children younger than 15 years. Anatomically, they affect the pons, midbrain and medulla oblongata. The tendency for pontine tumors tend to be malignant while tumors of the midbrain and medulla oblongata origin tend to be benign has been well described in the literature [5, 6, 10, 20, 24, 26, 27]. With the purpose of providing a guide for therapeutic strategy, some workers classify tumors of the brain stem not only by their anatomical location but also by their nature: diffuse, cervicomedullary, and focal [5, 6, 22, 24]. A diffuse neoplasm is poorly circumscribed and often occurs in the pons. Cervicomedullary tumors involve the caudal medulla oblongata and the rostral segment of the spinal cord. A focal neoplasm is a well-circumscribed mass, with or without associated edema. The prognosis is worse in children who present with rapid loss of neurological function including dysfunctions of multiple cranial nerves and of the cerebellum and pyramidal tract [2, 3, 7]. Only a few patients with clinical-radiological characteristics of this type survive for longer than 2 years after diagnosis [2, 3, 22]. Conversely, 6-year survival rates of 20–60% have been reported for those patients who present without these characteristics [3, 14].

The treatment of these brain stem lesions remains controversial. The clinical management reported in the literature varies widely, because it is complicated by the diversity of anatomical locations and tumor subtypes [24]. Ax-

ial neoplasms involving the midline structures in children can rarely be totally excised [11]. The usual surgical procedure performed in the past was a stereotactic or open biopsy, because any extensive removal of the tumor existing in the vital structure was highly detrimental [1, 2]. Some authors suggest that surgery would be indicated if the tumor exhibited exophytic growth or had a major cystic component [5, 10, 27]. However, other series suggest that well-limited solid intrinsic tumors are accessible for a total excision and the authors mention that surgery must be considered for all midbrain low-grade astrocytomas in children [10, 11, 18]. In different series, it has been demonstrated that extensive resection of low-grade brain stem gliomas can be attained with low morbidity and without mortality; major debulking is associated with an excellent long-term prognosis [3, 11, 26].

Most patients have been treated with combined surgery, radiotherapy (RT), and chemotherapy [7, 13]. However, RT does not always prevent tumor recurrence, and sometimes it is associated with the development of secondary malignancy in the radiation field, and also with intellectual and behavior disturbances [11]. For these reasons, RT must be reserved for the cases with tumor malignancy and rapid tumor recurrence, or for older children [11].

The availability of the operating microscope, the ultrasonic surgical aspirator, evoked potentials, and the laser has led to more aggressive and safer surgery [1]. Together with improvements in neuroimaging and surgical techniques, all this has made extensive resection of brain stem gliomas, previously thought to be non-surgical, possible in selected cases [1, 5, 6, 18, 26, 27].

Midbrain gliomas can be classified into three groups according to their location [20, 27]: tectal region, aqueductal region, and tegmental region. However, it is not uncommon for a tumor to involve more than one region at the same time. Vanderport et al. have identified another distinct subgroup of focal tumors, the “focal midbrain astrocytomas group,” which appear to present with a benign biological course: all tumors in this group are low-grade astrocytomas amenable to surgical resection with no mortality and minimal morbidity and are associated with an excellent long-term prognosis [26].

Patients with a focal midbrain tumor frequently exhibit both signs and symptoms of raised intracranial pressure caused by obstructive hydrocephalus, and neurological signs caused by pressure on the cerebral peduncles [18, 26, 27]. Vanderport et al. point out that 50% of focal astrocytomas of the midbrain occur in the tectum, producing obstructive hydrocephalus, while the other 50% occur in the tegmentum, causing long tract signs through compression of the cerebral peduncles and oculomotor nerve palsy through pressure on the nuclei. In children, midline astrocytomas tend to be histologically benign [11, 18, 24]. Focal gliomas involving the tectum or tegmentum have a better prognosis than diffuse tumors in the midbrain [8, 26].

Tectal tumors often present with a protracted course, and often do not show any growth in size [4, 17, 21]. Also, they rarely cause symptoms except for those of hydrocephalus. For these reasons, numerous reports indicate that these tumors should be observed without oncological treatment, but that the associated hydrocephalus needs to be treated. On the other hand, patients with tumors of the cerebral peduncle present with progressive neurological deficits, notably hemiparesis, and do need to be treated to prevent or reverse neurological symptoms.

In this communication, we present seven cases of cerebral peduncular astrocytomas in children who underwent radical tumor resection. Except for one patients who had previously received gamma knife irradiation, none received postoperative RT, as it was our intention to identify the natural history of these tumors without adjuvant therapy following aggressive tumor resection.

Clinical summaries

Cases classified as primary tumor of the cerebral peduncle were included in the study. The epicenter of the tumor was in the cerebral peduncle with frequent direct extension towards the pons caudally and/or the thalamus rostrally. These neighboring structures were displaced but not infiltrated. Also, they often extended to the neighboring cisterns. They can displace the temporal lobe further laterally or extend into the cerebellopontine angle caudally. During the period between 1993 and 2000, seven children with cerebral peduncle tumor were diagnosed and treated at the Children’s Memorial Hospital in Chicago, Illinois.

Clinical presentation

Table 1 shows the clinical presentations of the seven children with cerebral peduncle tumors. There were four girls and three boys. Their ages at diagnosis ranged from 4 years to 16 years, with a mean age of 10.4 years. The location of the tumor was the left cerebral peduncle in five and the right cerebral peduncle in two. All patients presented with contralateral hemiparesis, which was slowly progressive over periods of time ranging from 4 months to 6 years except in one patient (case 3) who presented with acute onset of hemiparesis and seizure due to an intratumoral hemorrhage. Other neurological deficits were contralateral hypesthesia in one (case 6), partial oculomotor nerve palsy in three (cases 2, 3, and 5), and hemianopia in one (case 7). Patient 1 had congenital deafness in the ear of the contralateral side, which was considered to be unrelated to the tumor. Four patients had hydrocephalus (cases 2, 4, 6, and 7).

All patients underwent computed tomography (CT) and magnetic resonance imaging (MRI) studies. Tumor sizes ranged from 2×3 cm to 5×6 cm. Three tumors were solid. Two patients had a mural tumor with a non-enhancing cyst wall. One showed a mixture of solid and cystic components, and another was primarily cystic with contrast-enhancing wall. All solid components of the tumor enhanced following intravenous contrast infusion. Exophytic tumor and cyst extended in various directions deep into the corona radiata, brain stem and/or cerebellopontine angle (Fig. 1).

Treatment

All patients underwent surgical treatment and radical tumor resection using a microsurgical technique. In cases with associated hy-

Table 1 Clinical summary of seven children with cerebral peduncle astrocytoma (*CPA* cerebellopontine angle)

Case	Age (years)/sex	Presentations	Location	Extension	Nature	Resection	Outcome	Present status
1	7/male	Right hemiparesis, right deafness	Left	Pons/CPA	Solid	Subtotal	Recurrence 6 years, 7 years	8.5 years (alive), stable disease
2	8/male	Right hemiparesis, left oculomotor	Left	Thalamus/ pons	Mixed	Subtotal	Involution	5 years (alive), no evidence of disease
3	13/female	Left hemiplegia, right oculomotor	Right	Ambient cistern	Solid/ hemorrhage	Total	No recurrence	12 months (alive), no evidence of disease
4	16/female	Left hemiparesis	Right	Thalamus/ corona radiata	Cystic	Total	No recurrence	2.5 years (alive), no evidence of disease
5	7/male	Right hemiparesis, left oculomotor	Left	Thalamus/ ambient, crural, CPA cistern	Mural tumor with cyst	Subtotal	Involution	3 years (alive), stable disease
6	13/male	Left hemiparesis, left hypesthesia	Left	Thalamus/ pons, crural cistern	Solid	Subtotal	Involution	3 years (alive), no evidence of disease
7	4/female	Right hemiparesis, right hemianopia	Left	Thalamus/ pons/temporal lobe/ CPA cistern	Mural tumor with cyst	Total	No recurrence	4 years (alive), no evidence of disease

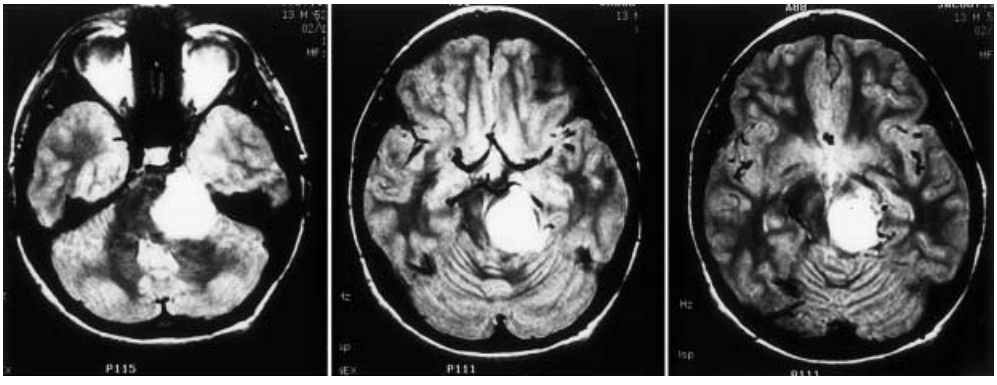

Fig. 1 Axial MRI of Case 1 showing cerebral peduncle astrocytoma with exophytic extension to the pons and cerebellopontine angle

drocephalus, an intraoperative ventriculostomy was made in the frontal horn of the ipsilateral lateral ventricle in order to attain brain decompression, except in one patient (case 2) who had an existing ventriculoperitoneal (VP) shunt. In patient 4, who had large cystic expansion toward the thalamus and the corona radiata, the cyst was first drained through an Ommaya reservoir and 6 weeks later the tumor was excised after significant reduction of cyst size and shrinkage of the tumor and its localization in the region of the cerebral peduncle.

In all patients, a subtemporal transtentorial approach through an ipsilateral temporal craniotomy was used for tumor resection. Except in cases 1 and 2, part of the fusiform and/or parahippocampal gyrus was partially resected when the temporal lobe was lifted in order to access the rostral portion of the tumor. In case 5, the temporal horn of the lateral ventricle was entered and a partial resection of the parahippocampal gyrus and hippothalamus was performed because of severe rostral extension of the tumor. In case 7, where similar rostral tumor extension was noted, the resection was aided by the use of a dental mirror to visualize and remove the rostral portion of the tumor.

The cerebral peduncle tumors in this series appeared to be relatively well demarcated, and in all patients gross tumor resection was considered to have been achieved by microsurgical techniques and operative ultrasound aspirator (Fig. 2). Based upon postoperative neuroimagings the extent of surgical resection was classified as total or subtotal (subtotal means the size of the residual was less than 10% of the original tumor size). Three patients had gross to-

tal resection and four had subtotal resection. Hydrocephalus was resolved following tumor resection and did not require CSF diversion shunt, except in patient 2, who had a pre-existing VP shunt.

Results

Tumor pathology showed juvenile pilocytic astrocytoma in six cases and gemistocytic astrocytoma in one (case 4). All were considered to be benign astrocytomas.

Following tumor resection, neurological evaluation showed improvement in three and no change in other two. The two remaining patients were worse postoperatively. Patient 5 had a short-term memory dysfunction and IIIrd cranial nerve deficit after surgery. The memory dysfunction was related to an injury to the left hippocampus. However, the memory deficits resolved in 3 months with speech therapy, though the patient had persistent partial oculomotor palsy, as noted preoperatively. In case 7, the hemiparesis worsened during the immediate postoperative period, but subsequently improved following physical therapy.

None of the patients received postoperative adjuvant therapy. Over the follow-up period ranging from 1 to 8.5 years, only one patient (case 1) had tumor recurrence. In case 1, two recurrences were noted during the follow-up period: the first time 6 years after the first surgery and the second time in the following year. On both occasions, subtotal resection of the recurrent tumors was performed through the same subtemporal approach. The residual tumor following the last surgery has remained stable in size during the ensuing 28 months. In case 2, as an initial treatment, a stereotactic biopsy and VP shunt placement was followed by gamma knife irradiation. However, 3 years later the patient presented with cystic tumor recurrence and underwent placement of an Ommaya reservoir into the cyst. However, he then showed worsening of his hemiparesis and developed oculomotor palsy due to progressive growth of the recurrent tumor. He underwent subtotal resection of the recurrence through a subtemporal approach. After surgery, clinical improvement was noted, with total resolution of his hemiparesis and oculomotor palsy. Also, spontaneous involution of the small residual tumor was noted on serial MRI studies. Similar involution was noted in cases 5 and 6 following subtotal tumor resection (Fig. 3). Patients in cases 3, 4, and 7, following a gross total resection, have remained free of recurrence for 1–4 years.

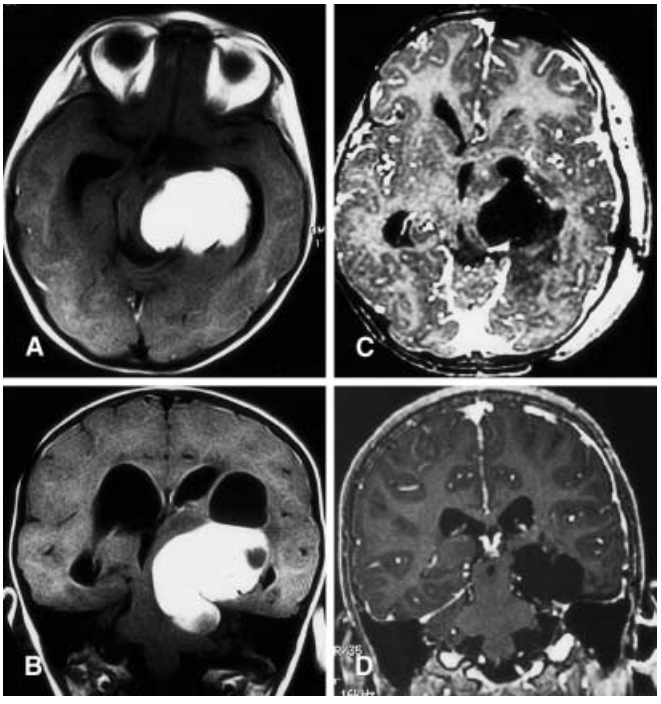

Fig. 2A–D Contrast-enhanced **A** axial and **B** coronal MRIs in case 7. Note massive extension of the tumor toward the thalamus superiorly, the temporal lobe laterally, and the pons and cerebellopontine angle in the posterior fossa. A dorsal extramural cyst further extends to the corona radiata. Postoperative contrast-enhanced **C** axial and **D** coronal MRIs show a total resolution of the benign astrocytoma of cerebral peduncle origin

Discussion

The midbrain is located between the pons and the thalamus and consists of the tectum and the cerebral peduncle. The smaller part of the midbrain posterior to the aqueduct is the tectum, which consists of the quadrigeminal plate. The anterior, larger, part, which is partly subdivided into two halves, is the cerebral peduncle. Each cerebral peduncle consists of the crus cerebri anteriorly, the tegmentum posteriorly and the substantia nigra between them. Just superolateral to the cerebral peduncle are the medial and lateral geniculate bodies laterally. The thalamus and the internal capsule lie rostral to the cerebral peduncle. Inferior to the cerebral peduncle is the pons.

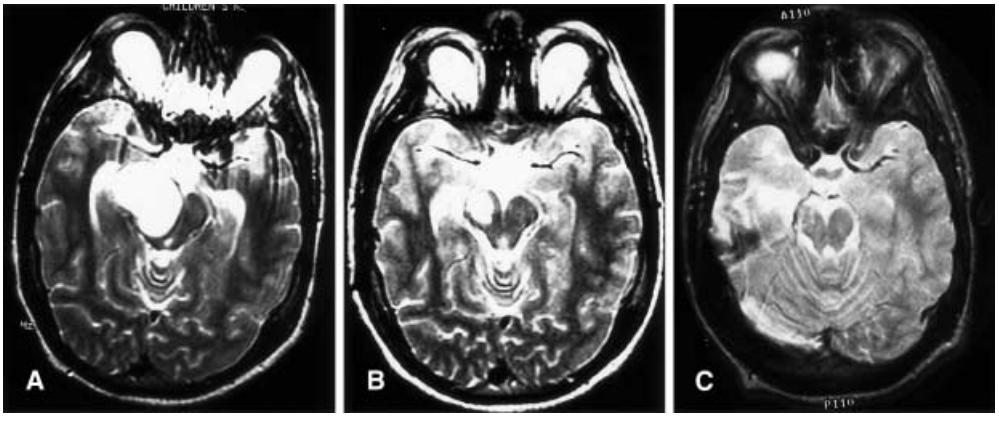

Fig. 3 **A** Axial T2-weighted axial MRI of case 5, showing a cerebral peduncle astrocytoma. This tumor extended further to the thalamus rostrally and to the pons caudally. **B** MRI 2 months after surgery shows a residual tumor in the cerebral peduncle. **C** MRI 9 months after surgery shows spontaneous involution of the tumor

The optic tract runs over the crus cerebri, crossing its junction with the internal capsule, close to the choroidal fissure.

The midbrain is a small structure, and tumors occurring in it can extend beyond its anatomical boundaries. Some may extend in an exophytic fashion to the surrounding cisterns, the crural and ambient cisterns laterally, the suprasellar cistern anteriorly and the cerebellopontine cistern inferiorly. Also, cysts can extend in various directions either into the surrounding brain substance or the cisterns. Because of anatomical proximity, the tumor origin is often vague, particularly in cases of large cerebral peduncle tumor extending in various directions. In the seven cases presented here, we considered the cerebral peduncle tumors not only as seen on preoperative neuroimagings but also in light of intraoperative findings and postoperative neuroimaging studies. It may be difficult to differentiate a pontine tumor extending into the cerebral peduncle from a cerebral peduncle tumor extending to the pons. The former shows enlargement of the basis and tegmentum of the pons that displaces the midbrain upward, and the edges of these tumors are often ill defined. The latter usually shows exophytic extension to the cerebellopontine angle, displacing a well-preserved pontine structure contralaterally or caudally. Following tumor resection, the pons with normal structural arrangement becomes clear on postoperative MRI.

Tumors of thalamic origin can extend caudally to the midbrain and vice versa. Earlier, it was often difficult to distinguish a thalamic tumor from a cerebral peduncle tumor by axial scans alone. However, three-dimensional projections provided by MRI have made it possible to differentiate these two different types of tumors, as the tumor of cerebral peduncle origin has its primary growth center in the midbrain.

Despite massive involvement of the cerebral peduncle, presenting symptoms are often limited to minor contralateral hemiparesis of lesser degree and signs of hydrocephalus. It is relatively rare for the patients to present with ocular palsy or involuntary movements related to the dysfunction of the midbrain tegmentum [26, 27].

The midbrain is a relatively uncommon site for brain stem tumors. Only 10% of all brain stem tumors originate primarily in the midbrain [24, 27]. In contrast to pontine gliomas, midbrain tumors tend to be benign. It has been well recognized that the tectal tumors tend to be indolent, and it is relatively rare for them to show radiographic progression during prolonged observation periods [4, 19, 21]. The tumors affecting the cerebral peduncle also show benign histological features in this series. This confirms reports of similar observations by previous authors. The pathology of all childhood focal midbrain tumors in both the tectal plate and the tegmentum reported by Vanderport et al. revealed non-pilocytic low-grade astrocytomas [26]. On the other hand, the series presented by Wang et al. showed that 23 of 35 (71%) were benign astrocytomas [27]. Their series consisted of both adult and pediatric patients: nine of ten children 16 years or younger had benign astrocytoma, while only 14 of 24 adult patients had benign astrocytoma.

The subtemporal approach used in this series provides access to both the posterior fossa and the thalamus and deep into the corona radiata. The temporal craniotomy is placed as low as possible to access the middle cranial fossa, and the craniotomy is centered at the plane of the external auditory meatus. A currently available frameless stereotactic device, which we used in two cases in this series, facilitates the localization and identification of the tumor. In order to reach the posterior fossa, section of the tentorial edge is needed. Care should be taken to avoid traumatizing the IVth nerve, which runs just under the medial surface of the tentorial edge. The posterior cerebral artery runs around the hypertrophic midbrain, and it should be preserved carefully.

When the temporal lobe is lifted, partial removal of the fusiform and parahippocampal gyrus minimizes retraction of the temporal lobe upwards and provides direct access to the lateral portion of the midbrain. Although the basal temporal gyrus may be associated with language function, no clear detrimental effects of resecting the fusiform gyrus or parahippocampal gyrus have been noted [12, 15]. We found a dental mirror provided an excellent view of the most rostral portion of the tumor for resection. One patient (case 5) whose tumor was resected through the hippocampus developed transient short-term memory loss. The optic tract is present horizontally at the uppermost corner surface of the cerebral peduncle. Also, the oculomotor nerve is often displaced by exophytic tumors extending to the crural and suprasellar cisterns. These neural structures should be carefully identified and preserved. Damage to the hippocampus, particularly on the dominant side, should be avoided. It is possible to use the skull base approach to the caudal pontine lesion via the transpetrosal approach [9, 16], but we felt it was rarely necessary for our patients.

Although the number is small and the follow-up period is limited to 1–8 years in the seven cases presented in this series, these cases demonstrate that aggressive tumor resection is possible with acceptable surgical morbidity and leads to prolonged remission time. Only one patient in this series had multiple recurrences, yet further tumor resection of recurrences resulted in an excellent long-term prognosis. Operative experience in the literature has shown that surgical resection can be performed with minimal morbidity when a distinct plane differentiates the neoplasm from normal anatomy [5, 6]. Even incomplete resection seems to have a beneficial effect on patients with low-grade brain stem gliomas, since it has been found that some gliomas can decrease in size or become stable after surgery [5, 11]. It has been demonstrated that the tumor recurrence rate is lower in cases with resection of 50% or more than in those with smaller re-

section [5, 11]. These benign astrocytomas in the cerebral peduncle undergo spontaneous involution even when total resection has not been attained. Similar spontaneous involution has been observed in other astrocytomas involving the brain stem in children [25].

Use of RT is controversial in these cases, since it does not necessarily prevent tumor recurrence [11]. Even gamma knife surgery may not prevent relapse, as shown in case 3. RT can be associated with the possibility of latent sequelae: there is a risk of malignancy developing in the radiation field among other side effects [23]. In this study, none received RT after surgery, even when residual tumor was present. However, all cases displayed a good response to surgical resection and an acceptable clinical evolution.

Conclusion

Most midbrain tumors in children are benign astrocytomas, and they are often amenable to surgical resection with acceptable risks. A subtemporal approach applied to these deep-seated tumors provides effective access to both the most rostral and the most caudal portions of the cerebral peduncle tumors. The removal of part of the fusiform or hippocampal gyrus prevents forcible retraction of the temporal lobe, but the hippocampus, particularly of the dominant side, should be preserved. Following total resection or even incomplete resection, these tumors are often stable or may involute, so that toxic ionizing irradiation should be reserved for specific cases.

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