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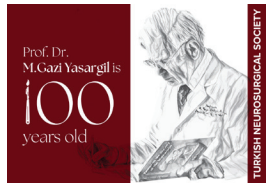


# Investigation of Clinical, Surgical, and Histopathological Findings of Pediatric Intracranial Meningiomas: A Single-Center Study

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## ABSTRACT

**AIM:** To report a series of pediatric intracranial meningiomas operated in a single institution, and to compare their features with the literature.

**MATERIAL and METHODS:** Using our hospital's automation system, patients under the age of 18 who had been operated in the last 11 years were identified. Data from these patients were collected and compared with the literature.

**RESULTS:** The mean age was 7.9 years old. Of the 10 patients, 8 (80%) were males, 2 were females (20%). The most common symptoms were cranial nerve palsies. When all MR and CT images were evaluated, peritumoral oedema was observed in 6 of the patients (60%), dural tail in 7 patients (70%), bone destruction in 3 patients (30%), and intratumoral calcification in 2 patients (20%). Histopathological diagnosis was made according to the World Health Organisation classification (2021) into grades 1, 2, and 3. Three patients (30%) had a typical meningioma (grade 1), and 7 patients (70%) had an atypical type (grade 2). Recurrence occurred in one of four patients with residual tumours.

**CONCLUSION:** Subtle and careful surgical approaches are the main treatment option and postoperative prognosis for pediatric meningiomas. Contrary to previous studies, the association of meningiomas with radiation exposure and NF was not common in our series. Further research is needed to understand the reasons for the differences between the pathophysiology of pediatric meningiomas and the adult form to ensure successful treatment.

**KEYWORDS:** Meningioma, Malignant meningioma, Intraventricular meningioma

**ABBREVIATIONS: MR:** Magnetic resonance imaging, **CT:** Computed tomography, **NF:** Neurofibromatosis, **EMA:** Epithelial membrane antigen, **GFAP:** Glial fibrillary acidic protein, **WHO:** World Health Organisation

## INTRODUCTION

Meningioma is the second most common form of primary brain tumour. Meningiomas originate from the arachnoid cap and meningothelial cells (28). They are generally observed in 4-5 decades. Meningiomas are rarely seen in children or adolescents and constitute only 0.4–4.1% of all pediatric tumours (22). Meningiomas are rare in newborns (21,27,31). Pediatric meningiomas have some differences from those occurring in adults. They have atyp-

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ical localisations, are more likely to be high-grade, and, unlike in adults, are more common in men (27). Intraventricular meningiomas constitute approximately 15% of pediatric meningiomas (17,20,27). While seizures are reported to be the most common symptom in pediatric patients, their incidence is less common in adults. Neurofibromatosis (NF) Type 2 and radiation have been reported to be associated with pediatric meningiomas. Surgery for pediatric meningiomas is difficult due to their location, and relapse risk is high as they tend to be high-grade. Radiotherapy and radiosurgery are recommended in relapse and residual cases. Herein, we report a series of pediatric meningiomas operated in our institution and compare their features with cases reported the literature.

## MATERIAL and METHODS

This study was approved by the Ethics Committee of Marmara University Faculty of Medicine (No: 09.2025.25-0171; Date: 21.02.2025).

In total, 10 cases of childhood intracranial meningiomas were operated at our institution in the last eleven years. The hospital's computerised system was used to collect data. Patients' age, gender, radiological characteristics, surgical approaches, extent of surgical excision, histopathological characteristics, need for radiotherapy, and prognosis of patients are studied and compared with the literature.

### Demography

The mean age was 7.9 years, with a range of 3–17. Half of the patients were in the first decade of life and the other half were in the second decade. Our series did not contain any infantile meningioma patients. Eight (80%) of the ten patients were male, and two (20%) were female. The ratio of males to females was 4:1. None of the patients had any history of radiotherapy for any oncological disorders, NF-2, or any other disease that can cause meningiomas.

### Symptoms and Signs

The most common symptoms were cranial nerve palsies and raised intracranial pressure signs. One of the patients presented with right abducens and oculomotor palsy, one with blurred vision, one with ptosis, and one with visual impairment. Only two of our cases had a history of focal seizures. The mean duration of symptoms was 2 months and 3 weeks. The age, gender, tumour localisation, symptoms, and duration of symptoms of the patients are summarised in Table I.

### Neuroradiological Findings

All patients underwent contrast enhancement cranial Magnetic Resonance Imaging (MRI) pre- and postoperatively, except patients 1 and 10. After performing cranial MRI, it was noticed that the tumours were iso-hypointense on T1 weighted images and iso-hyperintense on T2 and T2 FLAIR weighted images in all investigations. After contrast enhancement, all tumours enhanced homogeneously except for those of patients numbers 5 and 9, which were heterogeneously contrast-enhanced. On diffusion-weighted images, tumours of patients 2, 5 and 8 had total diffusion restriction; patients 6 and 9 had partial. No restriction was observed in diffusion-weighted imaging in the other four patients. Except for patients 3 and 9, all patients underwent a pre-operative brain CT scan. In CT, tumours were generally iso-hyperdense in nonenhanced series.

When all MR and CT images were evaluated, peritumoral oedema was observed in 6 of the patients (60%), dural tail in 7 patients (70%), bone destruction in 3 patients (30%), and intratumoral calcification in 2 patients (20%) (Figure 1). Brain MRI and CT findings are summarised in Table II.

### Localisation

The tumour of one patient was located at an occipital parasagittal location; two were intraventricular; three were tentorial; one patient had a medial sphenoid wing meningioma; one had a parietal convexity; one had an olfactory groove;

**Table I:** The Age (Years), Gender, Location of the Tumor, Symptoms, and Duration of Symptoms of the Patients

| | Age (years) / gender | Localization | Symptoms | Duration |
|---|---|---|---|---|
| **Patient #1** | 9/M | Right tentorial | Right abducens and oculomotor nerve palsy | 6 months |
| **Patient #2** | 13/M | Occipital parasagittal | Blurred vision | 4 days |
| **Patient #3** | 17/F | Left lateral ventricle | Headache, dizziness | 2 months |
| **Patient #4** | 10/M | Olfactory groove and nasal cavity | Left eye proptosis | 4 months |
| **Patient #5** | 8/F | Right sylvian fissure | Fatigue | Unknown |
| **Patient #6** | 13/M | Third ventricle | Amnesia | 4 months |
| **Patient #7** | 7/M | Right tentorial | Absence seizure | 3 months |
| **Patient #8** | 5/M | Left medial sphenoid wing | Left eye visual impairment | 2 weeks |
| **Patient #9** | 4/M | Right tentorial | Left eye ptosis | 3 months |
| **Patient #10** | 3/M | Left parietal | Seizure | Unknown |

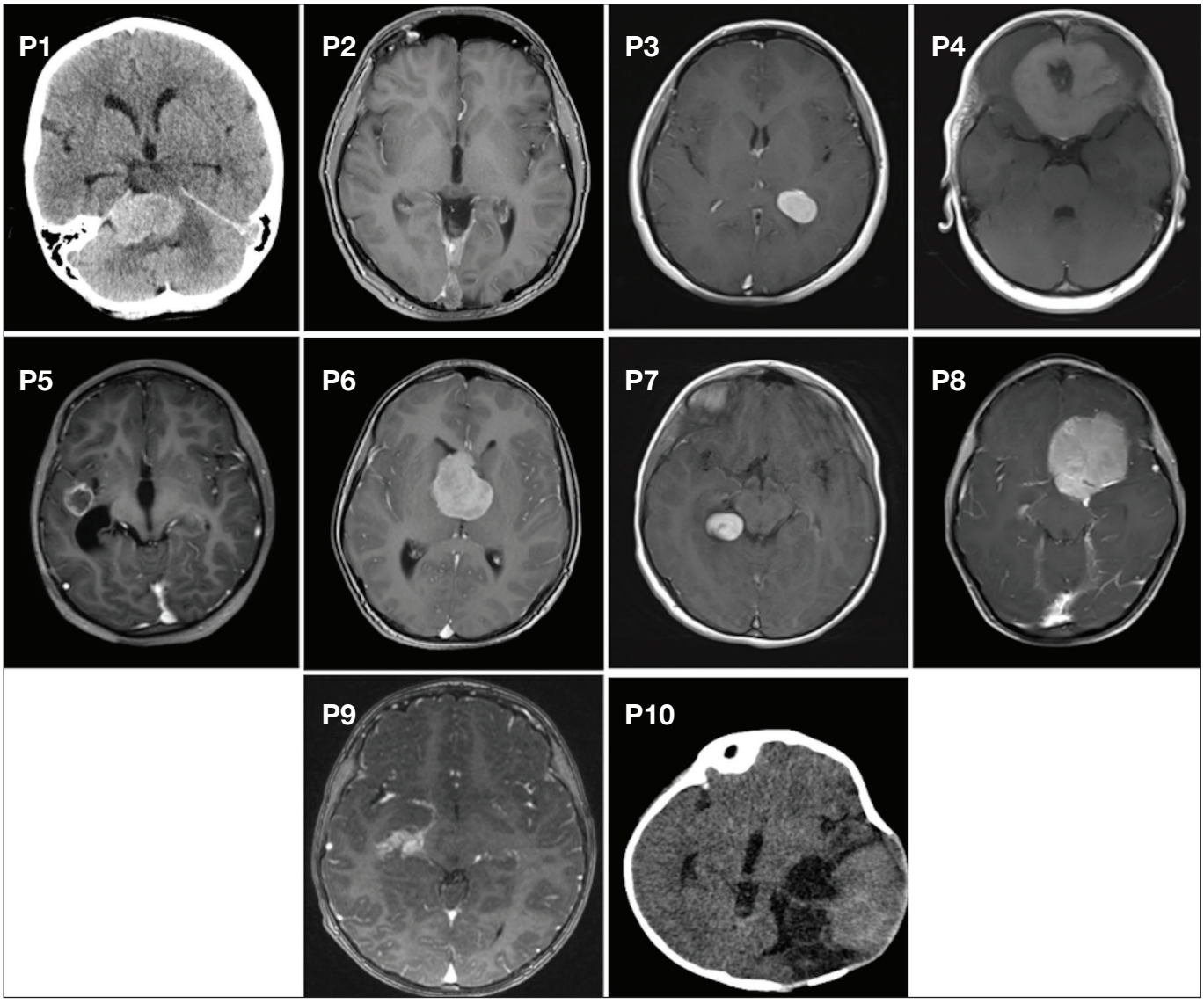


**Figure 1:** Axial T1-weighted contrast-enhanced MR and nonenhanced CT images taken pre- and postoperatively, shown by patient number (only brain CT was performed in patient numbers 1 and 10 preoperatively; because of this, nonenhanced CT images are included here).

and one a right Sylvian fissure tumour. Two of the tentorial meningiomas had grown to the middle fossa, and one into the cerebellopontine angle. The olfactory groove meningioma had destroyed the ethmoid bone and had grown to the nasal cavity.

### Preoperative Radiotherapy and Embolisation

None of our patients had a history of neoadjuvant radiotherapy for meningiomas. Cerebral angiography was performed on patient number 4 (olfactory groove meningioma). The tumour was fed by the meningeal branches of the bilateral ophthalmic arteries, the ethmoidal branches of the left maxillary artery, and partially by a frontal branch of the left middle meningeal artery. Interventional radiologists embolised the ethmoidal feeding arteries to reduce blood loss during surgery.

### Surgery (Tumour Excision and Others)

Total removal of the tumour was possible in 6 patients (60%). The patients with left parietal convexity and right Sylvian fissure-localised tumours had a previous history of surgery at another institution; these two patients were operated on due to recurrence. The Sylvian fissure-located tumour was tightly attached to the right middle cerebral artery branches; total removal was therefore impossible. The tumour of patient number 2, an occipital parasagittal meningioma, was only partially excised because it invaded the superior sagittal sinus. The gross mass of the giant left sphenoid wing meningioma of patient 8 was removed totally, with a minor residual tumour attached to the left posterior communicant and internal carotid artery. The olfactory groove (frontal base) tumour was extracted partially because of the residual mass invading

**Table II:** Preoperative MRI and CT Findings

| | Localization | T1 | T2 | T2 flair | T1+c | DWI | CT | Peritumoral edema | Hematoma | Dural tail | Bone destruction | Calcification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Patient #1** | Right tentorial | n/a | n/a | n/a | n/a | n/a | hyperdens | Yes | No | Yes | No | No |
| **Patient #2** | Occipital parasagittal | Hypointense | Hyperintense | Isointense | Homogenous | Restricted | Hyperdens | No | No | Yes | Yes | Yes |
| **Patient #3** | Left lateral ventricle | Isointense | Iso-hyperintense | Iso-hyperintens | Homogenous | Not restricted | n/a | Yes | No | No | No | No |
| **Patient #4** | Olfactory groove and nasal cavity | Isointense | Isointense | Isointense | Homogenous | Not restricted | Hyperdens | Yes | No | Yes | Yes | Yes |
| **Patient #5** | Right sylvian fissure | Hypointense | Iso-hyperintense | Isointense | Heterogenous | Restricted | Hyperdens | Yes | No | No | No | No |
| **Patient #6** | Third ventricle | Iso-hypointense | Isointense | Iso-hyperintens | Homogenous | Partial restricted | Iso-hyperdens | No | No | No | No | No |
| **Patient #7** | Right tentorial | N/a | Iso-hyperintense | Iso-hyperintens | Homogenous | Not restricted | Isointense | Yes | No | Yes | No | No |
| **Patient #8** | Left medial sphenoid wing | N/a | Iso-hyperintense | Hyperintense | Homogenous | Restricted | Iso-hyperdens | No | No | Yes | No | No |
| **Patient #9** | Right tentorial | Isointense | Iso-hyperintense | Isointense | Heterogenous | Partial restricted | n/a | Yes | No | Yes | No | No |
| **Patient #10** | Left parietal | n/a | n/a | n/a | n/a | n/a | Isodense | No | No | Yes | Yes | No |

the ethmoid bone and protruding into the nasal cavity (total excision was not possible after transnasal Ear Nose Throat (ENT) surgery). According to the Simpson excision grading system (38), we performed grade I excision in 6 patients, Grade II–III excision in one patient (sphenoid wing), and grade IV excision in 3 patients (olfactory groove, Sylvian fissure, and occipital parasagittal). In our series, there were three patients (numbers 2, 5, and 10) who were reoperated after recurrence. The frontal base meningioma patient had endoscopic transnasal surgery twice for the nasal and ethmoidal parts of the tumour by ENT surgeons. We performed another surgery for two patients beyond tumour excision. One patient with intraventricular meningioma underwent multiple surgeries due to hydrocephalus after tumour resection. Another patient had a history of surgery due to late-onset chronic subdural haematoma and had occipital parasagittal meningioma.

### Histopathology

Histopathological diagnosis was made according to the World Health Organisation classification (2021) into grades 1, 2, and 3. Three patients (30%) had a typical meningioma (grade 1), and 7 patients (70%) had an atypical type (grade 2) (Figure 2). There were no anaplastic type (grade 3) meningiomas in our series. Meningothelial and fibrosis subtypes were the most common in our patients. The chordoid, secretory, and transitional subtypes were each seen in one patient. Ki-67 index immunohistochemical staining was negative in one patient (patient #2) and was not studied in two patients (patient numbers 5 and 6). The mean Ki-67 index of grade 1 meningiomas was 3% for 3 patients, and the mean Ki-67 index of grade 2 meningiomas was 6.2% for 5 patients. Recurrence developed in a patient who underwent subtotal excision, and this patient's Ki-67 index staining was negative for the samples of both the original and second operations. Brain invasion was seen in 3 patients (30%) in our series, and the mean Ki-67 index of these three cases was 3.6% (Table III).

### Radiotherapy

In this series, three of our patients (30%) received radiotherapy after surgery. Patient number 2, who had occipital parasagittal meningioma, had a history of gamma knife radiosurgery

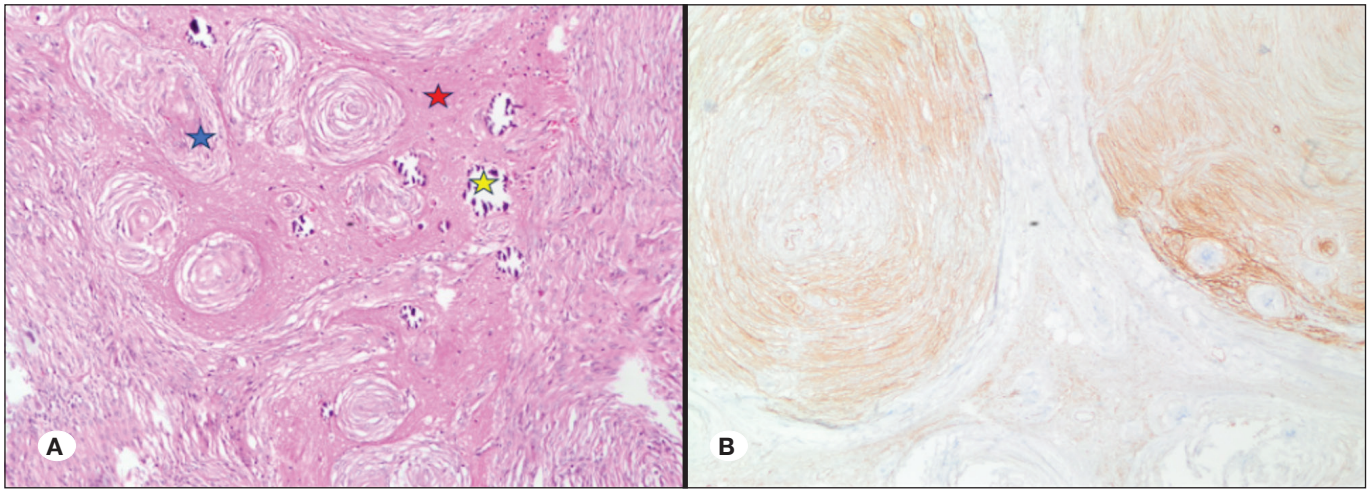


**Figure 2: A)** Microscopic appearance atypical meningioma with brain invasion: blue star—tumour; red star—brain parenchyma; yellow star—psammoma body. Haematoxylin and eosin (H&E) x10. **B)** Somatostatin receptor 2a immunohistochemistry, x10 (from patient number 9).

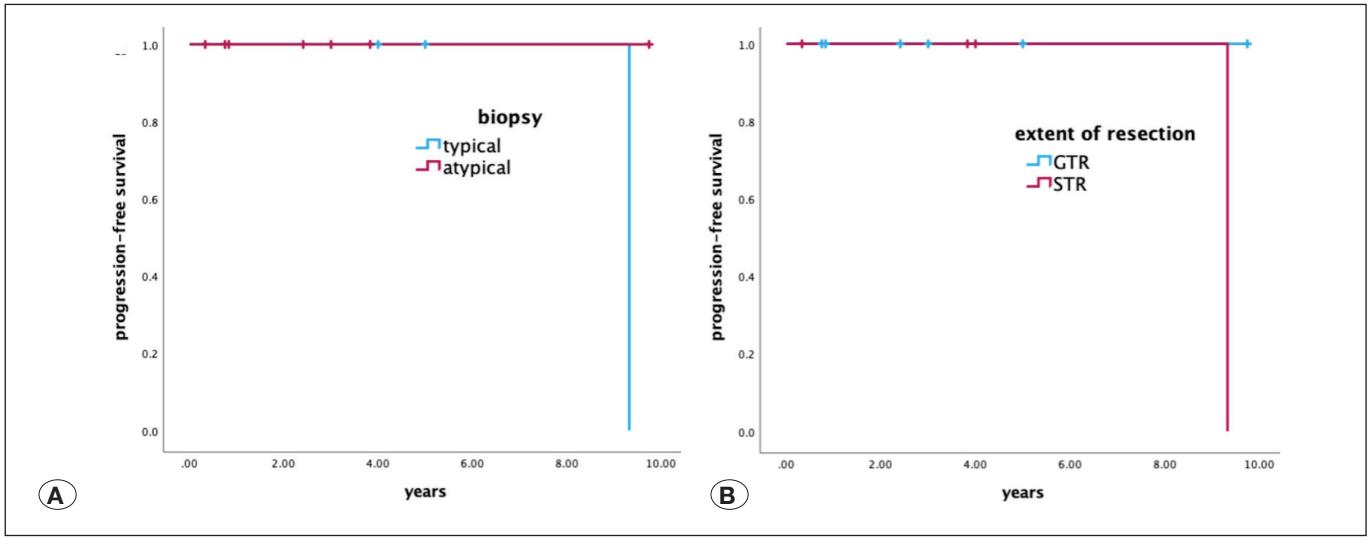


**Figure 3:** Kaplan-Meier curves displaying progression-free survival in relation to **(A)** biopsy, and **(B)** extent of resection.

performed twice after the first surgery; we then performed another surgery due to the recurrence of the tumour. However, total excision was not possible, and so the patient received radiotherapy after the second surgery. Patient number 5, with right sylvian fissure meningioma, had been previously operated on at another institution; we performed another surgery for residual tumour. Unfortunately, complete excision was not possible, as the residual tumour was attached to branches of the middle cerebral artery. This patient subsequently underwent gamma knife radiosurgery. Patient number 4, who had olfactory groove meningioma, underwent radiotherapy. Patient number 8, who had left sphenoid wing meningioma, received radiotherapy after surgery due to residue and a diagnosis of atypical meningioma with a Ki-67 index of 15%.

### Outcome

All patients survived treatment. Patient numbers 7, 8, and 9 were operated in the last ten months; further follow-up time is therefore required to assess relapse in these patients. The median follow-up time of patients was 4.13 years. Only 3 of the 10 patients who underwent surgery had new-onset symptoms postoperatively. Memory problems occurred postoperatively in the patient with third ventricular meningioma, which is improving with time. The patient with Sylvian meningioma suffers mild mental developmental problems. The patient with left sphenoid wing meningioma had right-side limb weakness after surgery; his motor performance improved with physiotherapy. Two of the patients had residual symptoms from before surgery. One of these two patients still has preoperative visual problems due to occipital parasagittal meningioma. The patient with olfactory groove meningioma has visual deficits and proptosis, due to the tumour invading the left orbital cavity.

**Table III:** Histopathological Features, Ki-67 Index and Brain Invasion Status of Patients are Shown

| | Localization | Pathology – WHO grade (2021) | Subtype | Ki-67 (MIB-1) | Brain invasion |
|---|---|---|---|---|---|
| **Patient #1** | Right tentorial | Atypical-II | Chordoid | 5% | No |
| **Patient #2** | Occipital parasagittal | Typical-I | Meningothelial | Negative | Unknown |
| **Patient #3** | Left lateral ventricle | Typical-I | Fibrous | 4% | No |
| **Patient #4** | Olfactory groove and nasal cavity | Typical-I | Transitional | 5% | No |
| **Patient #5** | Right sylvian fissure | Atypical-II | — | Unknown | Unknown |
| **Patient #6** | Third ventricle | Atypical-II | — | Unknown | No |
| **Patient #7** | Right tentorial | Atypical-II | Meningothelial + fibrous | 3% | Yes |
| **Patient #8** | Left medial sphenoid wing | Atypical-II | Meningothelial + fibrous | 15% | No |
| **Patient #9** | Right tentorial | Atypical-II | Meningothelial + fibrous | 3% | Yes |
| **Patient #10** | Left parietal convexity | Atypical-II | Secretory | 5% | Yes |

Only 4 (40%) of 10 patients had residual tumours, and tumour progression was detected in only one (occipital parasagittal). The 5-year progression-free survival was 100%, regardless of the extent of resection, for both typical and atypical meningiomas (Figure 3). Patients' residue, recurrence, reoperation, and follow-up status are summarised in Table IV.

## DISCUSSION

Meningiomas are slowly growing neoplasms that arise from meningothelial cells found within arachnoid granulations (28). Most meningiomas grow from these structures, which contain arachnoid cap cells and are concentrated in the walls of the major venous sinuses (3). Intraventricular meningiomas are thought to arise from arachnoidal cap cells that are trapped within the choroid plexus, the velum interpositum, or the tela choroidea (26).

### Epidemiology

Meningiomas generally appear in the 4$^{th}$ or 5$^{th}$ decade of life. However, they can occur at any age, even during foetal development. Pediatric meningiomas constitute an average of 1.5–1.8% of all meningiomas and 0.4–4.1% of all childhood tumours (22). Meningiomas in infants are extremely rare (21,31). The incidence of meningioma increases with age; pediatric cases generally present in the later part of the first decade or early in the second decade. Unlike adults, there is male dominance in childhood meningiomas (11,22). However, some authors, such as Glasier et al. and Darling et al., report an equal incidence, and others like Rochat et al. have found a female predominance, as seen in adults (5,14,33). The mean age of our cases was 7.9 years, with a male predominance. The male-to-female ratio was 4:1 in our series. Caroli et al. reported no difference between adults and children in genetic aberrations in meningiomas (4). There is a well-known association between NF-2 and meningiomas. According to some studies, meningioma is seen in 20% of patients diagnosed with NF-1 and NF-2. NF-1 and NF-2 are autosomal dominant diseases. Multiple meningiomas are more common in patients with NF-2, and malignant meningiomas associated with NF-2 show a worse prognosis (9,13,16,27,28). Perry et al. states that the histopathological features of sporadic and NF-2-associated pediatric meningiomas are generally the same, except for brain invasion (27,28). Deletions 1p and 14q, indicating tumour growth, are frequently seen in pediatric meningiomas, both NF-2-associated and sporadic. The large size of some pediatric meningiomas mentioned in several series, particularly in those containing NF pedigrees, suggests that NF is a sign suggestive of rapid tumour growth (1). Besides NF, Gorlin syndrome—also known as multiple basal cell carcinoma—is another familial tumour condition with autosomal dominant inheritance associated with meningiomas (34). There is no Gorlin syndrome or NF-associated case in our series. There is a well-established causal relationship between radiation and pediatric meningiomas. It has been shown that there is an observed risk of about 10 times higher for those who are exposed to radiation than for those who are not exposed (10,15,25). Radiation-induced meningiomas typically present at an earlier age, are more likely to be multifocal and exhibit higher degrees of atypia and mitosis. There is also some suggestion of a dose effect, with higher levels of radiation exposure being associated with shorter latency periods for the development of meningiomas (15). In our series, we had no patients with multiple meningiomas. There was only one patient (patient #10) with intratumoral cystic changes. According to the previously mentioned lack of NF-related findings and no previous radiation exposure history in this series, our patients are considered sporadic childhood meningiomas.

### Clinical Presentation

Pediatric meningiomas generally grow without any symptoms and often have become very large at the time of diagnosis. Clinical presentation of pediatric meningiomas varies according to the location of the tumour and may present with several

**Table IV:** Grade of Excision, the Status of Residue, Recurrence, Radiotherapy, Reoperation, and Survival Time are Shown

| | Localization | Grade of excision/ Simpson | Residue | Recurrence | Radiotherapy | Reoperation | Follow up time | Other situations |
|---|---|---|---|---|---|---|---|---|
| **Patient #1** | Right tentorial | Total/I | No | No | No | No | 9 years 9 months | - |
| **Patient #2** | Occipital parasagittal | Subtotal/IV | Yes | Yes | Yes (GK + GK + RT ) | Yes | 11 years 5 months | Subdural hematoma |
| **Patient #3** | Left lateral ventricle | Total/I | No | No | No | No | 5 years | - |
| **Patient #4** | Olfactory groove and nasal cavity | Subtotal/IV | Yes | No | Yes | No | 4 years | - |
| **Patient #5** | Right sylvian fissure | SubtotalIV | Yes | No | GK | No | 3 years 10 months | - |
| **Patient #6** | Third ventricle | Total/I | No | No | No | No | 2 years 5 months | Hydrocephalus |
| **Patient #7** | Right tentorial | Total/I | No | No | No | No | 9 months | - |
| **Patient #8** | Left medial sphenoid wing | Subtotal/ II-III | Yes | No | Yes | No | 4 months | - |
| **Patient #9** | Right tentorial | Total/I | No | No | No | No | 10 months | - |

symptoms like weakness, seizures, raised intracranial pressure signs, cranial nerve palsies, and visual disturbances. Seizure is the most common symptom of pediatric meningiomas; however, the incidence of seizures is lower than in adults (31). In contrast with the literature, seizure was seen in two patients in our series. The most common symptom and findings of our cases were cranial nerve palsies.

**Imaging Characteristics**

***CT***

The incidence of calcification and hyperostosis in CT scans is high, especially in pediatric meningiomas associated with NF (22). In a study by Rochat et al., 50% hyperostosis and 50% intratumoral calcification were reported (33). Liu et al. reviewed 122 childhood meningiomas with detailed CT images of tumour density, and reported that the incidence of tumour calcification, cystic generation, and intratumoral haemorrhage was 14.8, 21.3, and 1.6%, respectively (20). We saw no hyperostosis or intratumoral haemorrhage in our series. There was one case (patient #10) with intratumoral cystic changes and two cases (patients #2 and #4) with intratumoral calcification in our series.

***MRI***

MRI characteristics of pediatric meningiomas resemble those of adults. Meningiomas usually are iso-hypointense on T1, iso-hyperintense on T2, and well contrast-enhanced. However, dural tail is not a common sign in childhood meningiomas (13,30). Because of this feature, radiological diagnosis of intraventricular meningiomas is difficult. After examining the MR images of patients, we found the tumour characteristics on T1 and T2 images similar to the literature. Dural tail was noted in seven patients in our series, a higher incidence than stated in the literature. Contrary to another series finding, we found heterogenous contrast enhancement lesions just in two cases (20%).

**Localisation**

Convexity and parasagittal meningiomas are common in pediatric and adult patients (32). However, pediatric meningiomas are also seen in the intraventricular, skull base, and posterior fossa regions (27). Lack of dural attachment and a higher ventricular localisation rate are known features of pediatric meningiomas (39). Intraventricular meningiomas constitute approximately 15% of pediatric meningiomas (20), with the lateral ventricle the most common location (26). Surgery of these intraventricular tumours is risky because of venous anatomy. Miranda et al. reported posterior fossa clear cell meningioma without dural attachment in a 10-year-old child (23). Gendle et al. reported a 2-year-old child with velum interposition meningioma, located in the pineal region (12). There are a few pediatric meningiomas of tentorium origin cases in the literature (24,40). The tumours seen in three of our patients were of tentorium origin; two of these tumours had grown towards the middle fossa and one of them had grown towards the posterior fossa. Ventricular meningiomas constitute 20% of our series, with one of them located within the lateral ventricle and one in the third ventricle. Parietal convexity and parasagittal meningioma were seen in one case each.

### Pathology

The incidence of atypical and malignant meningiomas in adults is 8.6–12% (43). Some studies report that the incidence of atypical or malignant meningiomas in childhood is higher than in adults (13,27,31). Brain invasion is more common in pediatric meningiomas. Deletions of 1p and 14q have been reported and are associated with increased recurrence (30). It is known that pediatric meningiomas have a high incidence of atypical pathology, especially clear cell and papillary variants (22). In both pediatric and adult populations, EMA can be used to confirm the meningothelial phenotype. Glial cells in brain-invading meningiomas can be seen using GFAP (6,28). Although the correlations are less than in adult cohorts, the MIB-1 (Ki-67) proliferative index tends to correlate with tumour grade and, to a lesser extent, with the probability of recurrence in pediatric meningiomas (7,36). In a series of 23 pediatric meningiomas of grades 2 and 3 reported by Wang et al., the mean Ki-67 index was 2.4%. There is a correlation between the recurrence risk of high-grade pediatric meningiomas and the Ki-67 index (42). Nevertheless, a correlation between the Ki-67 index, progesterone receptor expression, and pediatric meningiomas is not yet well established. Three patients had a typical meningioma (WHO grade 1) in our series, while atypical meningioma (WHO grade 2) was detected in seven. There was no anaplastic meningioma in our series. The most common subtypes were meningothelial and fibrous meningiomas. The chordoid subtype was seen in one patient, as were the secretory and transitional subtypes. The Ki-67 index of grade 1 meningiomas was 3% for three patients, and the mean Ki-67 index of grade 2 meningiomas was 6.2% for five patients in our series. Recurrence developed in a patient who underwent partial excision, and this patient's Ki-67 index was negative. It was also found to be negative in the samples from the second operation of this patient. Brain invasion was seen in three patients, and the Ki-67 index was 3.6% for these cases.

### Treatment

The main treatment option for pediatric meningiomas is surgery with total excision of the tumour. If total excision is not possible, adjuvant radiotherapy may be used. Adjuvant radiotherapy is also recommended for high-grade meningiomas (31).

### Surgery

Excision of meningioma in the pediatric population is a neurosurgical challenge, because of the increased incidence of inaccessible location of the tumour, lower relative blood volume, and risk of massive blood loss. The aim of meningioma surgery is to remove the tumour with a wide dural margin. We were able to totally excise the tumours of six patients (60%), and macroscopic gross total or partial in four patients (40%). The main problems that prevented total removal were attachments to surrounding vascular structures and invasion of the anterior cranial base bone. According to the Simpson excision grading system, we excised the tumour with grade I in six patients, grade II–III in one patient, and grade IV in three patients.

### Adjuvant Radiotherapy

Postoperative radiotherapy may be beneficial after partial excision of the tumour in adults. However, radiotherapy can be risky for children because it can impair brain development. Some authors argue that re-operation is better than adjuvant radiotherapy (22). Tsurubuchi et al. used proton for residual tumours in the cavernous sinus wall in a 7-year-old patient with clear cell meningioma (41). Rochat et al. published that atypical meningiomas have longer survival and typical meningiomas relapse faster than atypical types (33). Ravindranath et al. performed radiotherapy for 11 of 31 patients in the 4500–5000 Gy dose range (31). Only two of our patients received radiotherapy after excision of their tumour. One patient had a history of two gamma knife radiosurgeries and radiotherapy.

### Radiosurgery

According to research by Attia et al., doses over 14 Gy have been associated with improved rates of progression-free survival (2). Kuhn et al. reported that WHO grade 2/3 meningiomas had local control rates of over 70% at 1 year, but 57% at 5 years with SRS (19). Gamma knife radiosurgery seems to be safe for residual, recurrent, and surgically inaccessible pediatric meningiomas (35). In our series, one patient has a history of receiving gamma knife surgery only once, and another patient twice.

### Outcome

Treatment and follow-up of pediatric meningiomas are difficult, because the probability of recurrence and character of the tumours are not predictable. According to Drake et al. and Sano et al., pediatric meningiomas have a worse prognosis (35% 10-year survival rate) than meningioma in an adult population (8,37). Perioperative mortality in childhood intracranial meningiomas was around 0.3–10 % (43). Mortality can be reduced by taking some precautions: complete excision of the tumour, preoperative controlling of bleeding, prevention of postoperative wound infection, administration of appropriate anticonvulsants for controlling seizures and antibiotic coverage. Patients with NF and skull base tumours have an increased risk of morbidity (18). We have no case with a fatal outcome in our series. Three of ten cases have new-onset symptoms postoperatively. Preoperative complaints persist in only two patients. Tumour progression was seen in only one patient in our series, in one of the four with residual tumours.

## CONCLUSION

Meningiomas are rare lesions in childhood. Our results also show that there is male dominance in children, unlike adults. Subtle and careful surgical approaches are the main course of treatment and postoperative prognosis. Contrary to previous studies, the association of meningiomas with radiation exposure and NF was not observed in our series. Any kind of radiotherapy may be helpful with residual lesions but should be applied only when necessary. Research is needed to understand the reasons for the differences between the pathophysiology of pediatric and adult meningiomas, to optimise treatment success.

**Declarations**

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**AUTHORSHIP CONTRIBUTION**

Study conception and design: EM, AD

Data collection: EM, KEA

Analysis and interpretation of results: CK, MS

Draft manuscript preparation: EM

Critical revision of the article: AD

Other (study supervision, fundings, materials, etc...): AD, SB

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