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ORIGINAL PAPER

Pediatric intracranial clear cell meningioma: a clinicopathological study of seven cases and literature review

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Abstract
Background In this study, we reported seven cases of pediatric intracranial clear cell meningiomas (CCMs) in our institution and reviewed the relevant literature to investigate the clinicopathological characteristics, treatment options, and prognosis of these rare tumors.
Methods From January 2005 to June 2016, we retrospectively reviewed seven pediatric intracranial CCMs in terms of their clinical data, preoperative MRI features, and prognosis. Moreover, a critical review of the English language literature was also conducted.
Results The patients consisted of two males and five females with a median age of 10.5 years (range 6–15 years) at initial surgery. Petroclival and cerebellopontine angle area was the most common location site (5/7). Accordingly, the most common initial manifestation was hearing loss (3/7), and the mean interval from onset of symptoms to admission was 6.8 months (1.5–24 months). Gross total resection was achieved in five patients. Of the six tumors with immunohistochemical records, MIB-1 labeling index varied from 3 to 20 % (mean 8.1 %). During the follow-up period (mean 76.9 months, range 16–180 months), four patients had experienced tumor recurrences and three patients died due to recurrences.
Conclusions Pediatric intracranial CCMs have a tendency to recur. There is a significant relationship between MIB-1 labeling index and recurrence. Gross total resection is recommended; if not available, adjuvant radiotherapy should be used to reduce the recurrent rate. In addition, postoperative MRI follow-up should be monitored at an interval time after resection.

Keywords Clear cell meningioma · Pediatric · Clinicopathological features · Prognosis

Introduction

Clear cell meningioma (CCM), recognized as WHO grade II, only constitutes 0.2 % of all subtypes of meningomas [1]. These tumors have a tendency to present in younger patients and represent a therapeutic challenge due to their propensity to recur and metastasize [2]. In pediatric population, meningiomas are uncommon, accounting for only 0.4–4.1 % of the pediatric age tumors and only 1.5–1.8 % of all intracranial meningiomas [3]. Thus, pediatric intracranial CCMs are very rare and seldom encountered.

Until now, only a limited number of intracranial CCMs have been reported in pediatric patients, and most of them are from case report [1, 4–7]. A considerable confusion exists in the clinical course, the histological and radiologic characteristics, and the treatment options and prognosis of these tumors. Moreover, because many striking differences of meningiomas have been noted between adults and children, any management approaches extrapolated from the treatment of adult CCMs should be carefully validated in children [8].

In this study, we reported seven new cases of pediatric intracranial CCMs in our institution and reviewed the relevant literature to analyze the clinicohistological characteristics and prognosis and further to investigate the proper treatment of pediatric intracranial CCMs.

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Materials and patients

We retrieved the medical records of pediatric patients who were diagnosed as intracranial meningiomas and underwent surgery in our department from January 2005 to June 2016. Among them, seven pediatric intracranial CCMs were identified. Their demographic data, presentation, physical examinations, surgery process, clinical course, and treatments were examined in medical and surgical reports. Simpson resection grades I and II were defined as gross total resection (GTR). In addition, Simpson resection grades III and IV were defined as subtotal resection (STR). Hematoxylin and eosin (H & E) staining and immunohistochemistry for progesterone receptor (PR), Ki-67, vimentin, glial fibrillary acidic protein (GFAP), S-100, and smooth muscle actin (EMA) were performed on tumor sections.

Their radiological data were screened from PACS in our hospital. The size of the tumor was defined as the greatest diameter of the enhanced tumor on all sections of MRI. The signal intensities of tumors on T1-weighted and T2-weighted MRI were categorized as either hypointense, isointense, or hyperintense relative to that of the cortical gray matter on the same MR images.

Follow-up data of the patients were obtained from our outpatient visits and telephone reviews. In this study, stereotactic radiosurgery was performed in case 1, conventionally fractionated was performed in case 4, and gamma-knife radiosurgery was performed in cases 3 and 5. All these radiotherapies were described as adjuvant radiotherapy in this study.

In addition, we performed a critical review of the English literature on pediatric intracranial CCMs on PubMed without time limit. Keywords used were as follows (single word or combination): “clear cell meningioma” and “pediatric,” “clear cell meningioma” and “children,” “clear cell meningioma” and “child,” “high-grade meningioma” and “pediatric,” “high-grade meningioma” and “children,” and “high-grade meningioma” and “child.” All the cases, series, and literature review lists were obtained and reviewed. Only those who were intracranially located and have adequate clinicopathological information pertinent to the analysis were included.

Results

Clinicopathological features and prognosis

This study included seven pediatric intracranial CCMs. Their clinical and pathological features are summarized in Table 1. The patients consisted of two males and five females with a median age of 10.5 years (range 6–15 years) at initial surgery. Petroclival and cerebellopontine angle (CPA) area was the most common location site (5/7). Accordingly, the most common initial manifestation was hearing loss (3/7), and the mean

Table 1 Clinicopathological features of seven pediatric intracranial clear cell meningiomas

Case	Age (years) /sex	Duration of symptoms/symptoms	Location	Excision degree	PR	Vimentin	EMA	GFAP	S-100	MIB-1 LI (%)	Discharge (KPS)	Adjuvant radiotherapy	Recurrence/ recurrent time/location	Died
1	F/6	6 months/headache, vertigo and gait ataxia	Left petroclival	Gross total resection	–	+	+	NA	NA	3 %	80	No	Yes/8 months/local	No
2	M/8	1.5 months/by accident	Right temporal convexity	Gross total resection	–	+	+	NA	NA	3 %	100	No	No/168 months	No
3	F/8	3 months/gait ataxia and reduced hearing	Right petroclival and cavernosus	NA	NA	NA	NA	NA	NA	NA	90	No	Yes/36 months/local	Yes
4	F/7	2 years/reduced hearing, 3 months/facial paralysis	Left CPA	Subtotal resection	+	+	–	NA	NA	10 %	90	Yes	Yes/15 months/local	Yes
5	M/15	6 months/headache, 1 months/lower extremity weakness	Left frontal parietal convexity (parenchymal)	Gross total resection	–	+	–	–	+	20 %	80	Yes	Yes/12 months/local	Yes
6	F/14	2 months/lower extremity weakness	Bilateral petroclival and cavernosus	Gross total resection	+	+	+	NA	–	5 %	80	No	No/15 months	No
7	F/14	5 months/reduced hearing and vomiting	Right petroclival	Gross total resection	+	+	+	–	NA	7.5 %	90	No	No/11 months	No

interval from onset of symptoms to admission was 6.8 months (range 1.5–24 months). GTR was achieved in five patients.

Microscopic examination and immunohistochemical findings were available in six cases (except for case 3 because her first surgery was not performed in our hospital). Light microscopic examination (H & E) revealed that sheets of polygonal or round cells filled with abundant clear cytoplasm were separated by bands of collage and hyalinized vascular stroma (Fig. 1a). The nuclei in the specimen were round or oval. The mitoses of the nuclei were not significant. Structure of vague whorls was seen in case 1 (Fig. 1b). Psammoma bodies were not found in all of these cases. Immunostaining of PR, EMA, and vimentin was positive for three cases, four cases, and all the six cases, respectively. MIB-1 labeling index (LI) varied from 3 to 20 % (mean 8.1 %).

Four patients suffered from local recurrences after the initial surgery with a mean recurrent time of 17.8 months. Notably, case 1, case 3, case 4, and case 5 experienced recurrences for four, six, two, and three times, respectively. Among them, case 3, case 4, and case 5 died due to the recurrences since 14 years, 69 months, and 48 months after their initial operation, respectively.

MRI features

Preoperative radiological data with MRI were available in five of them and are summarized in Table 2. All of these tumors were isointense on T1-weighted image (T1WI) (Fig. 2a), four out five of them were hyperintense on T2WI (Fig. 2b), and the tumors were strongly enhanced with contrast injection on T1WI (Fig. 2c, d). Two out five exhibited heterogeneous enhancement, and the other three exhibited homogeneous enhancement. Despite that dural tail sign was a significant feature for meningiomas on MRI, interestingly, all of the present cases showed no such signs.

Discussion and literature review

CCM is very rare in pediatric population. Giving its rarity, only 30 cases of pediatric intracranial CCMs were reported (Table 3). Thus, a total of 37 cases (including our cases) make up the current body of literatures. The clinical and pathological features of all these tumors are summarized in Table 4. From these data, the epidemiological factors and natural history of this tumor are becoming evident.

Clinical features

According to the previous literature review of the 18 cases of pediatric CCM (including intracranial and spinal), the mean age of the pediatric cases is 9 years [9]. In this present review, we found a higher mean age of 10.3 years in these patients. In addition, different from their female predominance, these tumors were more commonly seen in males, with a 1.5:1 male-to-female ratio, and this ratio is similar to that reported in the general pediatric meningiomas [10]. A proclivity of CCMs for the CPA area and the spinal column has been reported with almost equal frequency [11, 12]. In the present series focusing on the intracranial location, the CPA area was the most common location for pediatric CCMs (57 %, 21/37), followed by convexity location (16 %, 6/37) and posterior fossa (14 %, 5/37). The most common presentations were headache (44 %, 16/36) followed by cranial nerve symptoms (33 %, 12/36). In the cases with duration of symptoms, the time ranged from 1 week to 72 months with the mean time of 12 months.

Radiology

In line with the previous studies [13], these lesions in our five cases showed isointense on T1WIs, isointense or hyperintense on T2-weighted images, and marked enhancement on gadolinium administration on MRI. Meningiomas usually demonstrate dura-based growth, and “tail sign” could be constantly seen on MR images. The review data show a prevalence of dural tail ranging from 52 to 78 % in meningiomas [14, 15]. In addition, malignant lesions exhibit more common dural enhancement than the benign ones [16]. However, despite the relative malignant biological behavior, all of the present cases with preoperative MRI were lacking of dural tail sign, and it could be a characteristic radiographic finding on pediatric intracranial CCM.

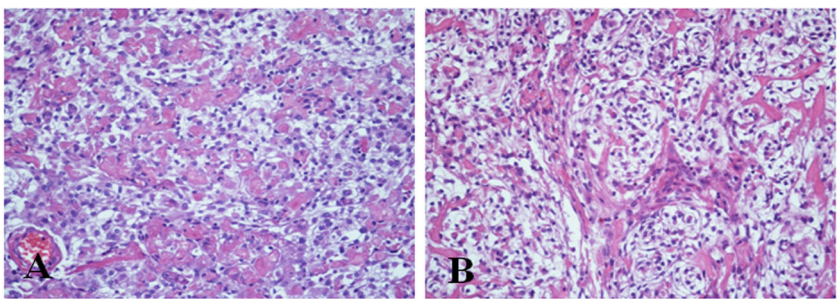

Fig. 1 H&E staining. **a** Tumor tissues consisting largely of sheets of polygonal or round cells filled with abundant clear cytoplasm were separated by bands of collage. **b** Structure of vague whorls could be seen in case 1 (original magnification ×20)

Table 2 MRI characteristics of present five pediatric intracranial clear cell meningiomas

Case	Tumor size (cm)	T1 weighted	T2 weighted	Tumor enhancement pattern	Shape of tumor	Tumor-brain interface	Edema	Dural tail sign
1	4	Isointense	Hyperintense	Homogenous	Regular	Clear	Absence	Absence
4	3	Isointense	Hyperintense	Homogenous	Regular	Clear	Absence	Absence
5	8	Isointense	Hyperintense	Heterogeneous	Irregular	Clear	Presence	Absence
6	5.5	Isointense	Isointense	Heterogeneous	Irregular	Unclear	Absence	Absence
7	5	Isointense	Hyperintense	Heterogeneous	Irregular	Unclear	Absence	Absence

Immunohistochemical findings

It is helpful for immunohistochemistry to diagnose CCM and differentiate them from other subtypes of meningiomas, as well as from other similar clear cell tumor entities, including ependymoma, microcystic meningioma, oligodendroglioma, and metastasis of renal clear cell carcinoma [2]. As described in the previous study, a membranous pattern of immunoreactivity for EMA and strongly reactive for vimentin just like other meningiomas could be observed in almost all CCMs, reflecting mesenchymal and epithelial properties. In addition, a tumorigenic role of nuclear progesterone receptor (PR) in meningioma has been suggested and PR staining appears in 77 % of these meningiomas [17]. Similarly, of all the pediatric CCMs in this study, vimentin, EMA, and PR staining appeared in 100 % (21/21), 86 % cases (24/28), and 57 % (4/7) cases, respectively. These results also suggested that not all the CCMs are immunoreactive to EMA staining. CCM includes more glycogen than the other meningioma subtypes, and it can be immunoreactive to GFAP, which is an atypical characteristic for meningiomas [2], but in this review, all the reported 14 cases were immunostained negative for GFAP. As a nuclear antigen, Ki-67 expresses during active phases of the cell cycle including G1, S, G2, and M phases [18]. A higher MIB-1 LI indicates shorter cell cycle times and faster tumor growth [19]. In the present series, the mean MIB-1 LI for pediatric CCM was 6.9 % (ranging from 2 to 20 %), which was intermediate between that of grade I and grade II

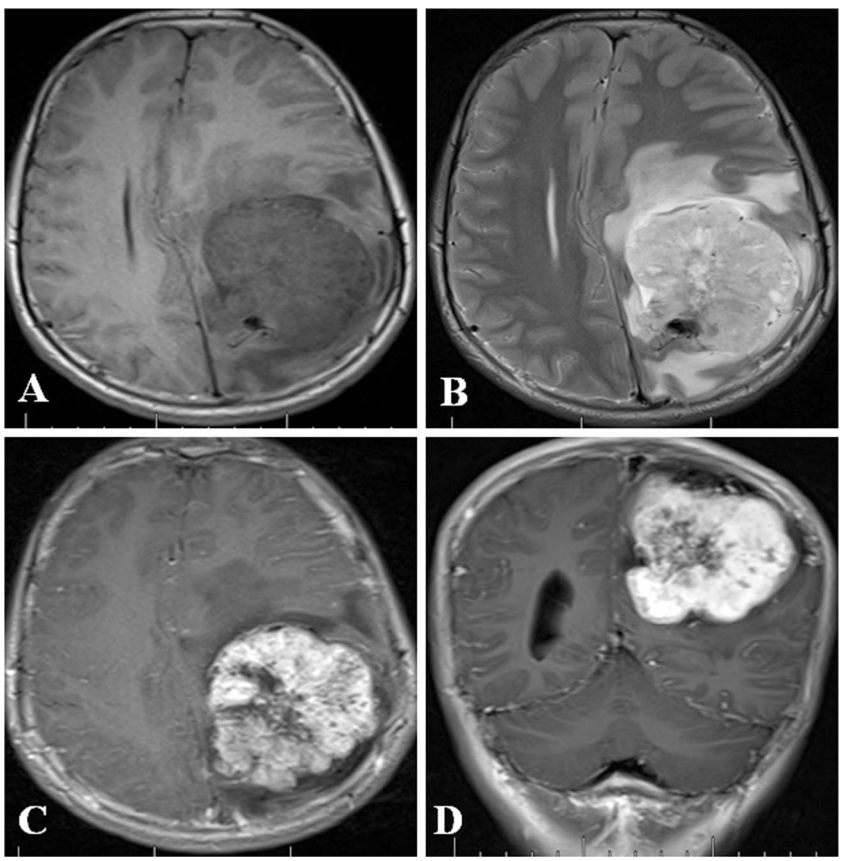

Fig. 2 Pediatric intracranial clear cell meningioma on MRI. **a** Tumors showed isointense on T1-weighted image. **b** Tumors showed hyperintense on T2-weighted image. **c**, **d** Tumors were strongly enhanced with contrast injection on T1-weighted image

Table 3 Summary of clinicoradiological characteristics of 37 patients

Clinical findings		
Sex	Male	22/37 (59 %)
	Female	15/37 (41 %)
Mean and median age (years)		10.3 years
Clinical presentation	Headache	16/36 (44 %)
	Cranial nerve symptoms	12/36 (33 %)
	Limbs symptoms	6/36 (17 %)
	Others	2/36 (6 %)
Mean symptoms duration (months)		12 months
Location of lesions	CPA	21/37 (57 %)
	Convexity	6/37 (16 %)
	Posterior fossa	5/37 (14 %)
	Tentorium	2/37 (5 %)
	Paraseller	1/37 (3 %)
	Middle cranial fossa	1/37 (3 %)
	Fourth ventricle	1/37 (3 %)
Resection degree	Gross total resection	28/35 (80 %)
	Subtotal resection	7/35 (20 %)
Immunohistochemical characteristics		
Vimentin	Positive	21/21 (100 %)
	Negative	0/21 (0 %)
EMA	Positive	24/28 (86 %)
	Negative	4/28 (14 %)
PR	Positive	4 (57 %)
	Negative	3 (43 %)
GFAP	Positive	0/16 (0 %)
	Negative	16/16 (100 %)
S-100	Positive	2/16 (13 %)
	Negative	14/16 (87 %)
Cytokeratin	Positive	0/8 (0 %)
	Negative	8/8 (100 %)
MIB-1 LI (mean)		6.9 % (2 to 20 %)
Treatment and prognosis		
Follow-up time (mean)		39.1 months (1.5 to 180 months)
Recurrence time (mean)		19.5 months (6 to 72 months)
Treatment		Recurrence/Not recurrence
Gross total resection + adjuvant radiotherapy		2/2
Gross total resection only		6/17
Subtotal resection + adjuvant radiotherapy		2/2
Subtotal resection only		1/0

conventional meningiomas [20]. This MIB-1 LI was lower than the reported mean of 9 % in the previous series of adult CCM [8]. It has been reported that MIB-1 LI is correlated with histological atypia and tumor recurrence, whereas other studies could not confirm the statistical significance [2, 6, 9, 17]. Among the 37 pediatric patients in our review, 21 of them had MIB-1 LI record. There was a significant relationship between MIB-1 LI and recurrence-free time (RFS) ($P = 0.017$, log-rank test) (Fig. 3). However, in this review, even CCM with low MIB-1 LI could recur [9].

Treatment and prognosis

CCM has a high risk of recurrence after resection compared with other meningioma subtypes. According to a previous study, the recurrence rate of CCM is as high as 61 % [17]. However, in this review, the rate was 34 % (11/32), with a recurrent mean time of 19.5 months (range 6–72 months). The reason could be the relatively shorter follow-up time. Notably, after the first recurrence, we found that as high as 78 % (7/9) of the patients would suffer the second recurrence with a

Table 4 Overview of cases with pediatric intracranial clear cell meningiomas

Authors/ references	Case	Sex/age (years)	Duration of symptoms/symptoms	location	Excision degree	PR	vimentin	EMA	Other histological features	MIB-1 LI (%)	Adjuvant radiotherapy	Follow-up time (months)	Recurrence/ time (months)	Distant recurrence
Zorludemir et al./1995 [17]	1	M/11	Progressive headache	Frontal convexity	Gross total resection	NA	+	+	(ER, S-100) negative	NA	No	18	Yes/13	Yes
	2	F/12	6 weeks/headache	Tentorial notch and posterior clinoid	Gross total resection	NA	+	+	(ER, S-100) negative	NA	No	24	No	No
	3	M/16	Headache, nausea, and vomiting	CPA	Gross total resection	NA	+	+	(ER, S-100) negative	NA	No	27	Yes/6	Yes
Shih et al./1996 [28]	4	M/12	Headache, papilledema	CPA	Gross total resection	NA	+	+	(S-100) positive/ (cytokeratin, GFAP) negative	NA	No	5	No	No
Teo et al./1998 [29]	5	F/2	3 months/head tilt, occasional dysphagia and right hemiparesis	Brainstem	Subtotal resection	NA	+	faint	(cytokeratin, S-100, synaptophysin, GFAP) negative	MIB-1 5.9 %	No	NA	NA	NA
Yu et al./2002 [30]	6	F/17	Headache, hearing loss	CPA	Subtotal resection	NA	+	+	NA	MIB-1 1 %	No	NA	NA	NA
Carrà et al./2003 [31]	7	M/7	Headache and back stiffness. Secondary to the spinal CCM removed 5 years ago	Posterior fossa	Gross total resection	NA	NA	NA	NA	NA	No	NA	NA	NA
Ahn et al./2005 [6]	8	F/7	Right facial weakness, right lateral gaze palsy, right hearing disturbance, sensation decrease of right cornea and face, impaired tandem gait	CPA	Subtotal resection	NA	NA	+	(PAS) positive/ (CD10, S-100, GFAP) negative	MIB-1 15–20 %	Yes	102	Yes/72	No
Jain et al./2007 [9]	9	M/11	3 months/ptosis, recurrent headache and hemiparesis	Parasellar	Gross total resection	NA	+	+	(CEA, cytokeratin, S100, GFAP) negative	MIB-1 2 %	No	84	No	No
	10	F/10	4 months/headache, vomiting, loss of hearing and vision	CPA	Subtotal resection	NA	+	+	(CEA, cytokeratin, S100, GFAP) negative	MIB-1 3 %	Yes	83	No	No
	11	M/18	12 months/headache, hearing loss	Tentorium	Gross total resection	NA	+	+	(CEA, cytokeratin, S100, GFAP) negative	MIB-1 2 %	No	24	Yes/24	No
Miranda et al./2009 [32]	12	F/10	6 months/occasional head tilt, right hemiparesis, gait instability and somnolence, mild dysphagia, bilateral horizontal nystagmus	Posterior fossa	Gross total resection	NA	NA	NA	NA	NA	No	6	No	No
King et al./2009 [33]	13	F/11	Headache, ataxia, bilateral horizontal nystagmus	Middle and posterior fossa (CPA)	Gross total resection	NA	+	−	(PAS, PASD) positive	MIB-1 5 %	No	1.5	No	No
Ma et al./2009 [34]	14	M/6	72 months/recurrent fever and seizures	Occipital parietal lobe	Gross total resection	NA	NA	+	(SMA, S100, GFAP) negative	NA	Yes	12	No	No
Takashi et al./2010 [7]	15	M/11	24 months/persistently remittent fever and mild headache	CPA	Gross total resection	NA	+	−	(CD3, CD20) positive	NA	No	12	No	No
Rakesh et al./2010 [35]	16	M/15		Frontoparietal convexity	Gross total resection	NA	+	+	(S-100, GFAP, synaptophysin,	MIB-1 8 %	No	18	No	No

Table 4 (continued)

Authors/ references	Case	Sex/age (years)	Duration of symptoms/symptoms	location	Excision degree	PR	vimentin	EMA	Other histological features	MIB-1 LI (%)	Adjuvant radiotherapy	Follow-up time (months)	Recurrence/ time (months)	Distant recurrence
			24 months/right-side weakness, left vision loss, seizures						cytokeratin, desmin) negative					
Burgan et al./2010 [36]	17	M/14	18 months/headache, nausea, vomiting and abdominal pain	Fourth ventricle extending through the foramen of Magendie	Gross total resection	NA	NA	+	NA	MIB-1 modest	No	6	No	No
Taha et al./2010 [37]	18	M/3.5	Long-term developmental delay, increasingly slurred speech, incoordination, learning difficulties, and hearing loss.	Posterior fossa originating from the medulla oblongata	Gross total resection	NA	NA	NA	NA	NA	No	6	No	No
Samer et al./2012 [27]	19	9/M	NA	Temporoparietal	Gross total resection	NA	NA	NA	NA	MIB-1 7 %	NA	27	Yes/14	No
Zhi et al./2012 [4]	20	4/M	2 months/progressively worsening left-side weakness, occasional head tilt	Posterior fossa extending to the foramina magnum	Gross total resection	NA	+	+	NA	MIB-1 negative	No	12	No	No
	21	8/M	2 months/progressive gait disturbance, right mouth angular salivation, and hoarseness along with dysphagia	CPA and temporal fossa	Subtotal resection	+	+	+	(GFAP, S-100, CD10, CD34, cytokeratin, desmin, ER) negative	MIB-1 5 %	Yes	18	No	No
Küster et al./2012 [21]	22	M/10	Left-sided deafness, atactic gait, and paresis of the left hypoglossal nerve.	CPA	Surgically (NA)	NA	NA	NA	NA	NA	NA	24	Yes/24	Yes
Chen et al./ 2011 + Wang et al./2013 [2, 13]	23	F/13	3 month /gait disturbance	CPA	Subtotal resection	NA	+	+	(PAS) positive (CD10, S-100, GFAP) negative	MIB-1 10 %	No	8	Yes/8	No
	24	M/8	2 months/raucitas, bucking	CPA	Gross total resection	NA	+	+	(PAS) positive (CD10, S-100, GFAP) negative	MIB-1 10 %	Yes	9	Yes/9	No
	25	M/9	6 weeks/right eye esotropia	CPA	Gross total resection	NA	+	+	(PAS) positive (CD10, S-100, GFAP) negative	MIB-1 2 %	Yes	14	No	No
	26	M/14	48 months/headache, hearing loss	CPA	Gross total resection	NA	NA	NA	NA	NA	No	11	No	No
Helen et al./2015 [38]	27	14/F	5 weeks/gait disturbance, deteriorating handwriting skills, and headache	CPA	Gross total resection	NA	+	+	(S-100, synaptophysin) negative	MIB-1 10 %	No	8	No	No
Rajan et al./2015 [5]	28	M/11	1 month/holocranial headache associated with vomiting	Right middle cranial fossa with extension	Gross total resection	NA	+	+	NA	NA	No	6	No	No

Table 4 (continued)

Authors/references	Case	Sex/age (years)	Duration of symptoms/symptoms	location	Excision degree	PR	vimentin	EMA	Other histological features	MIB-1 LI (%)	Adjuvant radiotherapy	Follow-up time (months)	Recurrence/time (months)	Distant recurrence
				into the infratemporal fossa										
Tareq A et al./2015 [1]	29	5/F	1 week/cephalgia, ataxia, and left sided torticollis	CPA and temporal fossa	Gross total resection	NA	NA	NA	(VEGFR, EGFR, PDGFR) overexpression	NA	No	96	Yes/12	No
Gerkes et al./2016 [39]	30	M/10	Recent onset of hearing loss and tinnitus of the right ear. He complained about blurry vision.	r CPA	Gross total resection	NA	NA	NA	NA	NA	No	12	No	No

NA not available

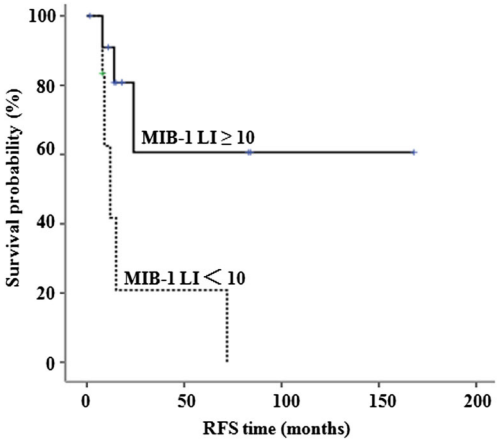

Fig. 3 Kaplan-Meier curves of recurrence-free survival by MIB-1 LI. Recurrence-free survival was significantly worse in pediatric intracranial clear cell meningiomas with MIB-1 LI ≥10 versus those with MIB-1 LI <10 ($P = 0.017$)

recurrent mean time of 24.9 months (range 7 to 48 months) from the second surgery, which has not been reported before. Moreover, after the second recurrences, 86 % (6/7) of patients would suffer from the disappointed third recurrences. Of these recurrences, distant recurrences were described in three cases, which included the recurrence in the spinal [17, 21]. Due to the rarity, it is still unclear whether the distant recurrences are caused by the capacity of CCM to metastasize or the plantation during the surgery. Thus, MR images including the entire neuraxis should be examined at regular intervals after the tumor resection, especially for those who have recurred more than once.

All of the patients were treated surgically, and 35 of them had a description for resection degree. Eighty percent of the patients (28/35) had GTR, while 20 % of them (7/35) had subtotal resection. Of all the patients who had GTR, 29 % (8/28) suffered from recurrences. In comparison, 60 % (3/5) of the patients with subtotal resection experienced recurrences. The results suggested that the recurrence rate of GTR is obviously lower than STR. Therefore, GTR should be considered the ultimate therapeutic objective in children. However, tumor location, vascularity, and tumor size often preclude the ability to perform a GTR to avoid the risk of intraoperative hemorrhage and neurological morbidity [18]. In this situation, as suggested by Traunecker, staged multiple procedures are recommended [22].

Based on adult retrospective series, adjuvant radiotherapy is recommended for WHO grade II or III meningiomas, incomplete resection, or local recurrence [22–24]. In pediatric meningiomas, the clear role of radiotherapy is still not very clear because of lack of evidence [18]. In this careful review, 23 % of the patients (8/35) have adjuvant radiotherapy. Of the patients who had GTRs, two out four patients with adjuvant radiotherapy experienced recurrences, and the other two patients with adjuvant radiotherapy did not. In comparison,

seven out of 24 patients who did not have adjuvant radiotherapy suffered from recurrences and the other 17 patients without adjuvant radiotherapy did not. Thus, it seems that adjuvant radiotherapy could not reduce the recurrent rate significantly in patients who had GTR. However, the current literature does not adequately explain this situation due to the small sample size. Some recurrences could also be caused by the unrecognized STR or more aggressive nature in some recurrent variants [11]. In addition, we found the patients who had STR but did not recur all had radiotherapy. Therefore, for those patients with tumor remnants, radiotherapy could be considered as an important treatment manner. However, in children whose central nervous system is more vulnerable to the damage of radiotherapy, the usage of this treatment should be balanced against the risk of late sequelae and increased incidence of secondary tumors [25–27].

In conclusion, CCM is an uncommon variant of meningioma and has a tendency to recur, especially after the recurrence for once. There is a significant relationship between MIB-1 LI and recurrence. Gross total resection is recommended; if not, STR should be followed by adjuvant radiotherapy to reduce the recurrent rate. After the resection, postoperative MR imaging follow-up should be monitored at an interval time.

Limitation

Our study has some limitations. First, despite that this is the largest reported number of patients, the total number is still small. Second, the review data were summarized from all the previously reported cases and from different institutions; thus, some assessments may not be identical (such as MIB-1 LI). Third, the follow-up time should be longer enough to validate the outcomes of these patients.

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Compliance with ethical standards

Conflict of interest The authors have declared no potential conflict of interest.

Ethical approval This research with approved by the research ethics committee of the Beijing Tiantan Hospital, Capital Medical University, Beijing.

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