# Prediction of High-Grade Pediatric Meningiomas: Magnetic Resonance Imaging Features Based on T1-Weighted, T2-Weighted, and Contrast-Enhanced T1-Weighted Images

*Hao Li, Meng Zhao, Yuming Jiao, Peicong Ge, Zhicen Li, Ji Ma, Shuo Wang, Yong Cao, Jizong Zhao*

■ BACKGROUND: **Prediction of high-grade meningiomas before surgery is essential to determine optimal treatment strategies; however, the relationship between radiologic features and malignancy of meningiomas in pediatric patients has not been clearly demonstrated. The aim of this study was to identify preoperative magnetic resonance imaging features that are significantly correlated with high risk of high-grade pediatric meningiomas.**

■ METHODS: **We retrospectively reviewed preoperative magnetic resonance imaging features and histopathologic diagnosis according to the 2007 World Health Organization classification system for intracranial tumors of 79 pediatric meningiomas from 2005 to 2015. World Health Organization grade II and III meningiomas were defined as high-grade meningiomas. The relationship between the radiologic findings and incidence of high-grade meningiomas was assessed initially with univariate analysis and then corrected by multivariate analysis.**

■ RESULTS: **According to univariate analysis, heterogeneous tumor enhancement, an unclear tumor-brain interface, tumor cyst, type of dural attachment, lateral location, positive capsular enhancement, and irregular shape of tumor were strong predictive factors for high-grade meningiomas. When corrected by multivariate analysis, an unclear tumor-brain interface ($P < 0.001$; odds ratio = 10.4; 95% confidence interval, 3.0–37.0), lateral location ($P = 0.014$; odds ratio = 4.9; 95% confidence interval, 1.4–17.6), and narrow base ($P = 0.001$; odds ratio = 8.3; 95% confidence interval, 2.5–27.1) were strong independent predictive factors for high-grade meningiomas.**

■ CONCLUSIONS: **In pediatric patients, meningiomas with an unclear tumor-brain interface, lateral location, and narrow base on preoperative magnetic resonance imaging are more likely to be high-grade meningiomas. Our results may be helpful in decision making regarding therapeutic strategies for pediatric patients with meningiomas.**

## INTRODUCTION

Histologic grading is one of the most important factors in determining the clinical outcome of meningiomas.[1] Prediction of high-grade meningiomas before surgery is important because it may help in determining the optimal treatment strategy, such as a wider craniotomy and a large dural substitute to treat high-grade meningiomas.[2,3] It also helps in making decisions about the follow-up interval for patients who receive conservative treatment or Gamma Knife radiosurgery without histologic diagnosis.[1] Previous studies identified several radiologic features, including heterogeneous tumor enhancement, an unclear tumor-brain interface, peritumoral edema, non–skull base location, and positive capsular enhancement, to be associated with malignancy of meningiomas.[2-4]

Meningiomas are uncommon in pediatric patients, accounting for only 0.4%–4.1% of tumors in pediatric patients and only 1.5%–1.8% of all intracranial meningiomas.[5] Compared with their counterparts in adults, the characteristics of meningiomas in pediatric patients differ significantly in various clinical and biologic aspects, including male predilection, cystic changes, a higher frequency of neurofibromatosis and high-grade meningiomas, lack of dural attachment, and phenotypic and genotypic aggression.[6-8] Pediatric high-grade meningiomas might have

**Key words**
- High-grade
- MRI
- Pediatric meningiomas
- Predictive factors

**Abbreviations and Acronyms**
CSF: Cerebrospinal fluid
MRI: Magnetic resonance imaging
WHO: World Health Organization

*From the Department of Neurosurgery, Beijing Tiantan Hospital, Capital Medical University; and China National Clinical Research Center for Neurological Diseases, Beijing, China*

*To whom correspondence should be addressed: Yong Cao, Ph.D.; Jizong Zhao M.D. [E-mail: caoyong6@hotmail.com or Zhaojz205@163.com]*

*Citation: World Neurosurg. (2016) 91:89-95.*
*http://dx.doi.org/10.1016/j.wneu.2016.03.079*

*Journal homepage: www.WORLDNEUROSURGERY.org*

*Available online: www.sciencedirect.com*

different magnetic resonance imaging (MRI) features compared with adult high-grade meningiomas. However, limited by the overall rarity, published data have not clearly identified radiologic features that are associated with high-grade pediatric meningiomas. The purpose of this study was to discover specific preoperative MRI features predictive of high-grade pediatric meningiomas.

## MATERIALS AND METHODS

### Patient Population

This study was approved by our institutional review board. From January 2005 to July 2015, 145 pediatric (≤18 years old) patients with histologically proven pediatric intracranial meningiomas underwent surgery in our department. After excluding the patients with recurrent meningiomas and preoperative radiosurgery, this study retrospectively screened 79 of these patients with complete preoperative MRI. Clinical data (sex and age) were collected from the hospital records. MRI data were examined and measured on the picture archival communication system at our hospital. The histopathologic slides of surgical specimens obtained before 2008 were reevaluated, and the histopathologic diagnosis was determined according to the 2007 World Health Organization (WHO) classification system for meningiomas. WHO grade II and III meningiomas were defined as high-grade meningiomas according to the previous literature.[2,9]

### MRI Acquisition

Preoperative MRI was performed with 1.5T machines (including TOSHIBA_MEC; GE Signa HDe) and 3T machines (including Siemens Trio, Siemens Verio; GE Signa, GE Discovery 750). The protocol for MRI was as follows: repetition time/echo time = 1680–2560 ms/8.6–26.72 ms for T1-weighted images, repetition time/echo time = 4800–6000 ms/92.22–123.31 ms T2-weighted images, matrix size = 256 × 256 to 640 × 640, section thickness = 5–7 mm, and field of view = 240 × 240 mm with small variations in different MRI machines. Contrast-enhanced T1-weighted images were obtained in the coronal, sagittal, and axial planes after intravenous gadolinium administration (0.1 mmol/kg body weight, maximum dose 7.5 mmol).

### MRI Features

MRI features (tumor volume, tumor location, tumor shape, T2 signal intensities, tumor contrast enhancement, tumor-brain interface, capsular enhancement, tumor cyst, brain edema, and type of dural attachment) were reviewed by 2 observers (H.L. and Z.L.) independently who were blinded to the pathologic results. The final decisions regarding MRI features were made after consensus of the 2 observers.

Tumor volume was determined by contrast enhancement of T1-weighted MRI after injection of gadolinium. The maximum perpendicular diameters (a and b) of the tumor were measured on the axial images, and the diameter in the coronal direction (c) was measured on the sagittal or coronal images. Then the volume of the tumor was approximated by the use of the formula for a spheroid: $V = 4/3\pi \times a/2 \times b/2 \times c/2$.[10,11]

Cranial meningiomas arising from the lateral cerebral convexity, cerebellar convexity, lateral ventricle, sphenoid wing (including greater wing, lesser wing, intermediate sphenoid ridge, and lateral sphenoid ridge), parasellar region, petroclival region, petrous apex region, jugular foramen, tentorial notch, lateral anterior area, middle skull base, and foramen were classified as having a lateral location. Cranial meningiomas arising from the falx, cerebellar tentorium, sagittal sinus, fourth ventricle, pineal region, olfactory groove, tuberculum, sella, clinoid, and foramen magnum were considered median line meningiomas.[12]

Tumor shape was classified as either regular or irregular based on the presence or absence of lobulation on the brain-tumor interface.[13] The signal intensities of tumor on T2-weighted MRI were categorized as hypointense, isointense, or hyperintense relative to the cortical gray matter on the same images. The pattern of tumor enhancement was classified as either homogeneous or heterogeneous based on solid component appearance on contrast-enhanced T1-weighted MRI.

The clear tumor-brain interface was confirmed by the distinct cerebrospinal fluid (CSF) layer with noted hypointensity on T1-weighted MRI and hyperintensity on T2-weighted MRI. A tumor interface without a distinct CSF cleft was defined as an unclear tumor-brain interface (**Figure 1**).[2]

Capsular enhancement was defined by the presence of an entire enhanced layer of the tumor-brain interface and classified as positive or negative.[2,3] A tumor cyst was confirmed by the presence of a cavity with hypointensity on T1-weighted MRI, hyperintensity on T2-weighted MRI, and the absence of enhancement on contrast enhancement of T1-weighted MRI. In addition, the cyst was classified as type I (centrally within the tumor), type II (peripherally within the tumor), or type III (in the adjacent brain) according to the location of the cyst with respect to the brain and enhanced tumor substance on contrast enhancement of T1-weighted MRI.[14] The presence of brain edema was judged as hyperintense extension adjacent to tumors on T2-weighted MRI.

According to the methodology of Chiechi et al.,[15] type of dural attachment was defined as a narrow base with tumor diameter greater than dural attachment or a broad base with tumor diameter equal to or smaller than dural attachment (**Figure 2**). Ventricular meningiomas were described as nonbase in this study because of the choroid plexus origin of meningiomas.

### Statistical Analysis

All data were analyzed using IBM SPSS statistics for Windows 19 (IBM Corporation, Armonk, New York, USA). The association between high-grade meningiomas and MRI features was examined by univariate and multivariate analyses. The $\chi^2$ and Fisher exact tests were used for univariate analysis. Subsequently, all variables with a significance of $P < 0.1$ in the univariate analysis were incorporated in a forward stepwise logistic regression for multivariate analysis. For univariate and multivariate analysis, $P < 0.05$ was considered statistically significant.

## RESULTS

The demographic data and radiologic characteristics of the 79 pediatric patients were summarized in **Table 1**. Among them, 3 patients had evidence of associated neurofibromatosis 2. All the meningioma specimens from patients with neurofibromatosis 2 were histopathologically diagnosed as WHO grade I. There were