Meningiomas account for approximately 20% of all intracranial neoplasms. This tumor type can be classified into 3 histological grades and 15 subtypes, according to the 2007 WHO classification of tumors of the CNS. Two of the most important factors that determine the prognosis of patients with meningiomas are the completeness of resection and the type of dural tail sign (DTS).

A radiopathological classification of dural tail sign of meningiomas

Laboratory investigation

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Object. The completeness of meningioma resection depends on the resection of dura mater invaded by the tumor. The pathological changes of the dura around the tumor can be interpreted by evaluating the dural tail sign (DTS) on MRI studies. The goal of this study was to clarify the pathological characteristics of the DTSs, propose a classification based on the histopathological and radiological correlation, and identify the invasive range of tumor cells in different types of DTS.

Methods. The authors retrospectively reviewed 179 patients with convexity meningiomas who underwent Simpson Grade I resection. All patients underwent an enhanced MRI examination preoperatively. The convexity meningiomas were dichotomized into various subtypes in accordance with the 2007 WHO classification of tumors of the CNS, and the DTS was identified based on the Goldsheer criteria. The range of resection of the involved dura was 3 cm from the base of the tumor, which corresponded with the length of DTS on MRI studies. Histopathological examination of dura at 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 cm from the base of the tumor was conducted, and the findings were correlated with the preoperative MRI appearance of the DTS.

Results. A total of 154 (86%) of 179 convexity meningiomas were classified into WHO Grade I subtype, including transitional (44 [28.6%] of 154), meningothelial (36 [23.4%] of 154), fibrous (23 [14.9%] of 154), psammomatous (22 [14.3%] of 154), secretory (10 [6.5%] of 154), and angiomatous (19 [12.2%] of 154). The other 25 (14%) were non–Grade I (WHO) tumors, including atypical (12 [48%] of 25), anaplastic (5 [20%] of 25), and papillary (8 [32%] of 25). The DTS was classified into 5 types: smooth (16 [8.9%] of 179), nodular (36 [20.1%] of 179), mixed (57 [31.8%] of 179), symmetrical multipolar (15 [8.4%] of 179), and asymmetrical multipolar (55 [30.7%] of 179). There was a significant difference in distribution of DTS type between Grade I and non–Grade I tumors (p = 0.004), whereas the difference was not significant among Grade I tumors (0.841) or among non–Grade I tumors (p = 0.818). All smooth-type DTSs were encountered in Grade I tumors, and the mixed DTS (52 [33.8%] of 154) was the most common type in these tumors. Nodular-type DTS was more commonly seen in non–Grade I tumors (12 [48%] of 25). Tumor invasion was found in 88.3% (158 of 179) of convexity meningiomas, of which the range of invasion in 82.3% (130 of 158) was within 2 cm and that in 94.9% (150 of 158) was within 2.5 cm. The incidence of invasion and the range invaded by tumor cells varied in different types of DTS, and differences were statistically significant (p < 0.001).

Conclusions. Nodular-type DTS on MRI studies might be associated with non–Grade I tumors. The range of dural resection for convexity meningiomas should be 2.5 cm from the tumor base, and if this extent of resection is not feasible, the type of DTS should be considered. However, for skull base meningiomas, in which mostly Simpson Grade II resection is achieved, the use of this classification should be further validated. The classification of DTS enables the surgeon to predict preoperatively and then to achieve the optimal range of dural resection that might significantly reduce the recurrence rate of meningiomas.

Key Words • convexity meningioma • skull base meningioma • Simpson grade • dural tail sign classification • pathological feature
mas are the extent of the resection and the tumor’s histological grade. Hitherto, the best predictor of recurrence was believed to be the Simpson grade. However, even after extirpation of meningioma under Simpson Grade I, the estimated rate of recurrence ranges from 10% to 32% within 10 years of resection.\(^{1,20}\) This might be attributed to the fact that the extent of resection, especially for the dura mater associated with the tumor, is not enough.

Additionally, the histological grades of convexity meningiomas might contribute to recurrence. With escalating histological grades, the range of tumoral invasion of dura and surrounding tissue might increase. The pre-surgical prediction of the range of dura invaded by tumor cells might aid in achieving more complete resection.\(^1\)

The change in the peritumoral dura mater is depicted as the DTS on MRI studies. Since its description in 1989, a handful of studies has analyzed the histopathological characteristics of DTS. Tumor invasion, increased loose connective tissue, angiogenesis, dilated vessels, and reactive hyperplasia are phenomena that correspond to the DTS. However, the precise nature of the DTS with respect to the pathological changes is not well understood.\(^{16,18,19}\)

We propose a classification of the DTS based on the radiological-pathological correlation, and provide evidence for the range of invasion of peritumoral dura by the tumor cells.

### Methods

A total of 179 patients with histologically confirmed intracranial convexity meningiomas diagnosed between May 2005 and May 2010 were included in the study. There were 127 female and 52 male patients. The mean age of the patients was 59 ± 11.3 years (mean ± SD; range 15–81 years). The inclusion criteria of the study were as follows: 1) well-defined DTS on Gd-DTPA–enhanced MRI studies; 2) initial surgery performed in our hospital; 3) no prior radiotherapy; 4) a single lesion in each patient; and 5) good neurological functional status and Karnofsky Performance Scale score > 90.

All patients underwent primary surgical treatment in our institute. The surgical approach in each patient was selected based on the location of the tumor. The extent of tumor removal was graded according to the Simpson criteria. All 179 convexity meningiomas received Simpson Grade I resection. The greatest range of the dural resection in this group was 3 cm from the base of the tumor, which correlated with the DTS on MRI studies.

The MRI examinations were performed with a 3-T machine (General Electric Signa EXCITE HD). The MRI protocol included the following sequences: T1-weighted images (TR/TE, 436/21 msec), T2-weighted images (TR/TE 5000/125 msec; echo train length 8), and FLAIR images (TR/TE/TI, 9000/145/2100 msec). Slice thickness was 5 mm, and the field of view varied between 18 and 30 cm. We also obtained axial, coronal, and sagittal T1-weighted images after the administration of 0.1 mmol/kg of body weight of Gd-DTPA. All the examinations were recorded on hard disk. The assessment of DTS was accomplished using the following criteria (Goldsher et al.\(^3\)): 1) presence of the DTS on at least 2 consecutive sections cut through the tumor at the same site and in more than one imaging plane; 2) greatest thickness adjacent to the tumor and tapering away from it; and 3) enhancement more intense than that of the tumor itself. The images were studied, implementing a double-blind review procedure, by 2 neuroradiologists. Those images with the same findings by both the neuroradiologists were included in the analysis of results. The features that were analyzed included the appearance and the length of the DTS. That length was analyzed using Picture Archiving and Communication Systems software (Nanfang Hospital, Guangzhou, China), and was the estimated maximum extent of the dural involvement when measured perpendicular to the outer margin of the meningioma. The longest length of each DTS was measured, and if the DTS had more than one tail, the length would be the mean length of both tails.

The 179 convexity meningiomas and the part of the adjacent dura mater corresponding to the DTS that had been resected during operations were fixed in 10% formalin and embedded in paraffin, as a part of our routine procedure. The dura mater was stained with H & E and examined 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 cm from the base of the tumor (Fig. 1). Inversion was defined by 1 neuropathologist, based on the presence of tumor cells in the dura mater and the gross appearance of the affected dura.

Statistical analysis was performed with a statistical software package (SPSS 16.0; TEAM EQS, 6th edition, 1337). The Kruskal-Wallis test and the Pearson chi-square test were used to assess statistical significance. A p value < 0.05 was considered statistically significant.

### Results

Of 179 convexity meningiomas, 154 tumors were classified in the WHO Grade I subtype, including transitional (44 [28.6%] of 154), meningotheial (36 [23.4%] of 154), fibrous (23 [14.9%] of 154), psammomatous (22 [14.3%] of 154), secretory (10 [6.5%] of 154), and angiomatous (19

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Fig. 1. A pathological specimen of resected convexity meningioma and the part of the adjacent dura mater corresponding to DTS fixed in 10% formalin and embedded in paraffin (left). The dura mater was stained with H & E (left) and examined 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 cm from the base of the tumor.
Dural tail sign classification of meningiomas on MRI

TABLE 1: Number of DTS types among different tumor subtypes in 179 patients with meningioma

<table>
<thead>
<tr>
<th>Tumor Subtype</th>
<th>Smooth</th>
<th>Nodular</th>
<th>Mixed</th>
<th>Symmetrical Multipolar</th>
<th>Asymmetrical Multipolar</th>
<th>Total</th>
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<td>8</td>
<td>18</td>
<td>2</td>
<td>14</td>
<td>44</td>
</tr>
<tr>
<td>meningothelial</td>
<td>3</td>
<td>6</td>
<td>14</td>
<td>2</td>
<td>11</td>
<td>36</td>
</tr>
<tr>
<td>fibrous</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>psammomatous</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
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<td>2</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>angiomatous</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>1</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>atypical</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>12</td>
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<td>anaplastic</td>
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<td>3</td>
<td>1</td>
<td>0</td>
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<td>5</td>
</tr>
<tr>
<td>papillary</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>total</td>
<td>16</td>
<td>36</td>
<td>57</td>
<td>15</td>
<td>55</td>
<td>179</td>
</tr>
</tbody>
</table>

[12.3%] of 154). The other 25 were non–Grade I (WHO) tumors, including atypical (12 [48%] of 25), anaplastic (5 [20%] of 25), and papillary (8 [32%] of 25). The DTSs in different subtypes are summarized in Table 1.

Based on MRI findings, the DTS was classified into 5 types: smooth (16 [8.9%] of 179), nodular (36 [20.1%] of 179), mixed (57 [31.8%] of 179), symmetrical multipolar (15 [8.4%] of 179), and asymmetrical multipolar (55 [30.7%] of 179). Figures 2 and 3 depict the classification of DTS. The following is a description of each type of DTS. For the smooth type, the dural tail commences from the base of the tumor and smoothly and uniformly extends to the end. The length was mostly 2–3 cm; however, in a few cases it was > 3 cm (Figs. 2A and 3A). For the nodular type, the dural tail appears beaded with nodular hyperplasia. The length in most cases was within 3 cm (Figs. 2B and 3B). The mixed type was the most common type, representing the typical form of DTS. For this type, the dural tail commences with the nodular enhancement and turns smooth as it extends. There might be a transitional zone between the nodular and smooth appearances. The length was 2–3 cm in most tumors (Figs. 2C and 3C). For the symmetrical multipolar type, it was characterized by more than one tail; however, each tail of the DTS was noted to have the same pattern. It was the least common type, and the length of each dural tail was variable (Figs. 2D and 3D). For the asymmetrical multipolar type, each tail of the DTS exhibited different patterns, and the length of each tail was arbitrary (Figs. 2E and 3E).

The smooth-type DTS was characterized by histopathological findings of vessel dilation (6 [37.5%] of 16) and inflammation of the dura (10 [62.5%] of 16) (Fig. 4A and B), both of which could be depicted on the MRI studies. All of the smooth-type DTSs were encountered in Grade I tumors. The extent of tumor invasion was within 1.5 cm of the base of tumor; that was the lowest of all DTS types. The mechanism of this type can be speculated to be as follows: the blood supply to the meningioma is from the adjacent dura mater, via its point of attachment. The invading tumor cells obstruct the vessels, leading to congestion of the adjacent dura, which is followed by proliferation of loose connective tissue and dural inflammation. This type was commonly encountered in skull base meningiomas, such as tuberculum sellae and petroclival meningiomas, in which the tumor has a higher potential to impede the dural vessel flow, given the tight adherence between 2 layers of dura and the lack of space in the skull base.15

Tumor invasion was the characteristic of the nodular-

Fig. 2. The appearance of different types of DTS on MRI studies. A: Smooth type, with dural tail commencing from the base of the tumor, smoothly and uniformly extending to the end. B: Nodular type, with the dural tail appearing beaded with nodular hyperplasia (arrows). C: Mixed type, with the dural tail commencing with the nodular enhancement and turning smooth as it extends (black arrow). There might be a transitional zone (white arrow) between the nodular and smooth appearances. D: Symmetrical multipolar type, with more than one tail, each tail of the DTS displaying the same pattern (arrows showing both tails with the mixed-type presentation). E: Asymmetrical multipolar type, with more than one tail, each tail of the DTS displaying different patterns (white arrow showing that the tail is the nodular-type presentation and black arrow showing the smooth-type presentation).
type DTS, in which the tumor cells invade the proximal dura, followed by extension to the distal dura. The range of invasion was consistent with the length of the DTS. This type was more commonly encountered in non–Grade I tumors (Fig. 4C).

The mixed-type DTS was characterized by typical pathological changes in the dura. The tumor invasion began at the proximal dura and extended to a certain distance, but did not extend to the end of the DTS (Fig. 4D). The distal dura displayed reactive hyperplasia, the occurrence of which preceded the invasion by tumor cells. This phenomenon led to a mixed type of appearance of this DTS. A transition zone between the proximal and distal tail was characterized by the mixture of the tumor cells and the inflammatory reaction (Fig. 5).

The symmetrical and asymmetrical multipolar–type DTSs could present with combinations of the smooth, nodular, and mixed type of DTS. We found that these 2 types were rare in skull base tumors. The potential locations for these 2 types of DTS were the convexity and the tentorium, where the attachment of dural layers is relatively loose, so that the dural tails can expand in all directions. The range of invasion in tumors with the 5 types of DTS is summarized in Table 2.

Based on the WHO subtype classification of the cerebral tumors, the convexity meningiomas were dichotomized into WHO Grade I tumors and non–Grade I tumors. The atypical, anaplastic, and papillary subtypes

Fig. 3. Model graphs of DTS on MRI studies. A: Smooth-type DTS, characterized by histopathological findings of vessel dilation and inflammation of the dura. The range of tumor invasion for the smooth type was the lowest of all DTS types. B: Nodular type; tumor cells invading the proximal dura, and then extending to the distal dura. The range of invasion was mainly consistent with the length of the DTS. C: Mixed type; tumor invasion beginning at the proximal dura and extending to a certain distance, but not extending to the end of the DTS. The reactive hyperplasia evolves in the distal dura. Black arrow showing the transitional zone. D and E: Symmetrical and asymmetrical multipolar-type DTS, which can present with combinations of the smooth-, nodular-, and mixed-type DTSs on MRI studies.

Fig. 4. Histopathological findings in the dura mater of different types of DTSs (arrows in the insets correlate with the corresponding site on MRI studies). A and B: Photomicrographs showing the pathological features of smooth-type DTS, with (A) demonstrating vessel dilation (black arrows) and (B) showing inflammation of the dura (black arrow) from the commencement of DTS. C: Photomicrograph showing the pathological features of nodular-type DTS; tumor invasion is evident up to the terminal part of the dura corresponding to DTS (black arrow). D: Photomicrograph showing the transitional zone (black arrows) of mixed-type DTS; tumor invasion begins at the proximal dura and extends to a certain distance, but not to the end of the DTS. The distal dura displays reactive hyperplasia (white arrow).
were classified into the non–Grade I group and the others into the Grade I group. The difference in distribution of DTS types between Grade I and non–Grade I tumors was statistically significant (p = 0.004, Fig. 6). However, no significant difference in distribution of DTS type was found within the groups (p = 0.818 and p = 0.841, Figs. 7 and 8). Figure 9 shows length of DTS types according to numbers of cases. The statistically significant difference between the types and lengths of DTS was evident on a Kruskal-Wallis test. The mean rank analysis revealed that the length of DTS in the smooth type was longest (112.69), followed by symmetrical multipolar (105.47), mixed (96.98), nodular (80.39), and asymmetrical multipolar (78.24) types (mean ranks shown in parentheses) (Kruskal-Wallis test: $\chi^2 = 11.043, p = 0.026$).

The incidence of tumor invasion of dura mater was 88.3% (158 of 179), which varied with the type of DTS ($p < 0.001$, Fig. 10). The incidence of invasion in the mixed type was the highest (54 [94.7%] of 57) and that in the smooth type was the lowest (7 [43.8%] of 16) of all DTS types in the study cohort. Figure 11 shows the invasive range of 179 meningiomas. The difference between the range of invasion and types of DTS was statistically significant on the Kruskal-Wallis test. The mean rank analysis revealed that the nodular type (118.36) of DTS exhibited the most extensive dural invasion, which was followed by the mixed type (97.25), the asymmetrical multipolar type (85.45), the symmetrical multipolar type (77.53), and the smooth type (27.69) (mean ranks for types shown in parentheses; Kruskal-Wallis test: $\chi^2 = 37.477, p < 0.001$). The invasive range was within 2 cm in 82.3% (130 of 158) of invasive tumors, and within 2.5 cm in 94.9% (150 of 158)—the invasive range for all tumors in this study was within 3 cm. In smooth-type DTS, the range of tumor invasion was within 1.5 cm in 100% (7 of 7). It is necessary to stress that the “incidence of tumor invasion” and the “extent of dural invasion” are 2 different terms; the former entails whether the tumor cells invade the dura mater, and the latter implies that the cells have invaded the dura mater and extended to adjacent dura mater. The incidence of tumor invasion is highest in the mixed-type DTS, but the most extensive dural invasion is seen in nodular-type DTS.

**Discussion**

The specific pathological changes of dura mater found in our study could be used to classify the DTS. The classification of the DTS can provide useful information for preoperative strategies, and it can aid in predicting the extent of the dura to be resected, which could significantly reduce recurrence of meningiomas. The rate of recurrence has been correlated with the extent of resection since the seminal description of the Simpson grading system for resection of meningiomas. Although recent re-

![Fig. 5. Comparison of pre- and postoperative MRI studies of a case of frontal meningioma. A: Preoperative MRI study showing mixed-type DTS. The DTS is long, and the arrow designates the transitional zone. B: Postoperative MRI study showing that the proximal dura and the transitional zone were resected, and the distal dura (arrow) was retained. C: Preoperative MRI study showing nodular-type DTS (arrow). D: Postoperative MRI study demonstrating partial resection of the dura (arrow). E: Follow-up MRI study obtained 9 months postsurgery showing tumor recurrence. The location of recurrence was the same as the location of residual dura (arrow).]
ports have challenged these criteria as the sole predictor of recurrence, they are the most accepted criteria to date. The recurrence rate in Simpson Grade II is reported to be 2-fold compared with Grade I resection of benign meningiomas, evidently related to the regrowth of the neoplastic cells escaping the dural coagulation. Nevertheless, most convexity meningiomas are easily resected under Simpson Grade I, but the adequate range of resection should be ensured. In 1993 Kinjo et al. demonstrated that with Grade 0 resection of meningiomas, which was approximately 2 cm from the margin of the lesion, none of the tumors recurred on clinical and radiological follow-up ranging from 1 to 10 years. However, they excluded patients with malignant meningiomas, and the 37 patients included in their series had a single, histologically benign meningioma. Indeed, we have detected the range of dural invasion beyond 2–2.5 cm, but that beyond 3 cm is not found, even with malignant tumor.

Our study demonstrates that in 94.9% of convexity meningiomas, the invasive range of dura was within 2.5 cm from the tumor attachment, which could be considered as a sufficient range of resection. However, a wide resection might not be feasible in locations such as the falx and parasagittal sinus, and in such cases the presurgical identification of the DTS type might aid the extirpation. For instance, the dura mater corresponding to the smooth-type DTS manifests a lower rate of tumor invasion; the range of invasion was < 1.5 cm, and the resection range should be as well. Furthermore, in nodular-type DTS, the range of tumor invasion was mostly the same as the length of the DTS on MRI studies. In contrast, the length of mixed-type DTS does not represent the range of tumor invasion. We believe that because the nodular appearance on the MRI studies corresponds to tumor invasion, if the 2.5-cm range of resection is not available, the transition zone should be identified and removed.
In our study, however, the incidence of tumor invasion in nodular- and mixed-type DTS was not 100%. This implies that not all of the areas with a nodular appearance on the MRI studies represent tumor invasion. We conceive that such a nodular appearance might represent the eminences due to dural hyperplasia that are displayed on MRI studies as nodular- or mixed-type DTSs without any pathological evidence of invasion. Because the number of cases demonstrating this variety of nodular DTS was very few in this cohort (2 in nodular type and 3 in mixed type), all the nodular appearances can be considered as invasion. Additionally, in multipolar-type DTS, characterized by more than one tail extending in different directions on MRI studies, the complete resection of dura mater corresponding to the DTS observed on MRI might be impossible, in which case the dura corresponding to the nodular tail should be resected. The appearance of each tail in multipolar-type DTS is of great significance in preoperative strategies, such as designing the bone flap.

The extirpation of skull base meningiomas was achieved under Simpson Grade II resection, due to the proximity of the tumor to vital structures such as cranial nerves and major vessels, so that the dura was not available for histopathological analysis. Consequently, using this DTS classification for skull base tumors might not be reasonable. However, we speculate that because both the skull base and convexity meningiomas originate from the arachnoid cap cells, they might possess the same bio-

**Fig. 8.** Bar graph showing DTS types among WHO non–Grade I tumors. The smooth type cannot be seen in this group, and the difference in distribution of DTS types among non–Grade I tumors was not statistically significant (Pearson test: $\chi^2 = 2.927, p = 0.818$).

**Fig. 9.** Bar graph showing the length of DTS types according to the number (N) of cases.

**Fig. 10.** Bar graph showing the incidence of invasion by tumor cells of different types of DTS. The incidence of invasion was different in the 5 types of DTS. The highest incidence is evident in the mixed-type (54% [94.7%] of 57), whereas the lowest is in smooth-type DTS (7% [43.8%] of 16) (Pearson test: $\chi^2 = 36.297, p < 0.001$).

**Fig. 11.** Bar graph showing the invasive range (in cm) of 179 meningiomas under Simpson Grade I resection.
logical characteristics if the pathological subtype is the same. Based on this conception, the DTS classification for convexity meningiomas could be extrapolated to that for skull base meningiomas.

Although the validity of this approach is questionable, the histopathological features of each type of DTS in convexity tumors and skull base tumors might be comparable. It is believed that skull base meningiomas are less invasive than convexity meningiomas. In our clinical experience, the smooth type is the most common DTS encountered in skull base meningiomas. This implies that the pathological changes in the dura mater around the tumor might be attributed to inflammation and hyperplasia, not to tumor invasion. Consequently, if the dura mater around the tumor cannot be resected, it can be dealt with by repeated coagulation with a bipolar device. Indeed, for skull base meningiomas with nodular-type DTS on MRI studies, the total resection of corresponding dura, along with the repair of the skull base defect to prevent CSF leakage, should be attempted. It is noteworthy that the tumor cells in the dura corresponding to nodular-type DTS are relatively resistant to heat generated by a bipolar coagulation, so if the dura cannot be resected, a laser knife could be used instead of a bipolar coagulation device. The laser knife can gasify the dura and bone, and has the advantage of less heat radiation, thereby protecting the surrounding structures.

The strength of our study includes the unique radiological and pathological correlation of the DTS in a relatively large cohort of meningiomas. The weakness of the study includes the absence of skull base meningioma specimens, which precludes the contemplation of the histopathological changes in this group of meningiomas, and necessitates extrapolation of the correlation of the results of MRI studies and histopathological investigations from the convexity meningiomas. This approach could be validated after a long-term follow-up. One of the potential weaknesses might be the under- or overestimation of the length of the dural tail on MRI studies because the angle of intersection of the image and the dural tail might vary. However, we attempted to overcome it by measuring the longest dural tail from the sagittal, axial, and coronal plane, and performing thin-slice MRI or using a navigation system to ensure dural involvement before surgery.

Conclusions

We propose the classification of the DTS based on the radiological and pathological findings in the dura mater. The presurgical knowledge of the type of the DTS and the range of invasion of dura corresponding to the DTS is crucial, for it might enable meticulous resection and thereby decrease the rate of recurrence. As in convexity meningiomas, resection of the involved dura should extend at least 2.5 cm from the base of the tumor, and if that range of resection cannot be achieved, the type of DTS should be identified to set the resection range.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Qi, Liu, Pan, Fang. Acquisition of data: Qi, Liu, Pan. Analysis and interpretation of data: Qi, Liu, Pan. Drafting the article: Qi, Liu, Pan. Silky. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Qi. Statistical analysis: Qi, Liu. Administrative/technical/material support: Qi. Study supervision: Qi.

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