Differentiation between benign and malignant meningiomas using diffusion and perfusion MR imaging

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Purpose

Meningiomas are the most common primary nonglial neoplasm of the brain in adults, representing 15-20% of all intracranial tumors [1]. There are three types of meningiomas based on malignant behavior: common benign (grade I), atypical (grade II) and malignant (grades III-IV) (WHO 2000) [2]. MRI plays a crucial role in the pre-operative assessment of brain meningiomas [3]. Although meningiomas do have some identifiable imaging features on conventional MR images, no special features has been found to be reliable in the predicting tumor grade[4]. For this reason, the clinical role of functional MR procedures, such as PWI and DWI has become an important area of investigation [5,6,7]. The degree of MR perfusion abnormality reflects the degree of microvascularity, an important biological marker of tumor grade and prognoses [8, 9, 10].

Our purpose was to investigate the utility of diffusion-weighted (DW) and perfusion-weighted (PW) MR imaging to differentiate benign and malignant meningiomas which were verified histologically[11, 12].

In this study, we compared DW MR imaging between benign and atypical/malignant groups of meningiomas to estimate the reduce ADC value for optimal tumor grading and describe imaging features of differentiation of atypical/malignant and typical meningiomas. Perfusion MR imaging using a relative cerebral blood volume (rCBV) and corresponding mean time to enhance (rMTE) were measured in the tumor parenchyma and in the peritumoral edema.
Methods and Materials

29 patients with meningiomas (16 women, 13 men; mean age 46 years, age range 23-67 years) underwent conventional, diffusion/perfusion-weighted MRI (DWI/PWI) before surgical resection. 12 common benign (WHO Grade I), 10 atypical (WHO Grade II) and 7 malignant (WHO Grades III and IV) were verified histologically. Conventional MRI revealed the ordinary signs of tumor. We analyzed the absolute apparent diffusion coefficient (ADC) and normalized ADC (NADC) ratio, the maximum rCBV and the corresponding relative mean time to enhance (rMTE) ratio between benign, atypical and malignant meningiomas in tumoral and peritumoral regions. 

MRI examination were performed on 1.5T machine (Signa, GE Medical Systems, Kutaisi, Georgia).

MRI examination protocol consisted of pre-contrast conventional MRI followed by DWI, PWI and finally post-contrast T1 weighted images.

We recorded the apparent diffusion coefficient (ADC) and normalized ADC (NADC) ratio, maximum rCBV and the corresponding rMTE values from the solid portion of the tumor, peritumoral area and contralateral white matter. The differences between the means of benign and malignant meningiomas were compared using an independent-samples t-test. A p-value of less than 0.05 was considered to indicate statistical significance.
Results

On conventional MRI all tumors were correctly diagnosed as meningiomas by evaluating the pre- and postenhancement images. The parenchyma of more than half of the benign meningiomas (n=17, 59%) was isointense on T1-weighted images, and showed homogeneous enhancement after contrast medium administration (Figure 1). Adjacent bone destruction was found in 30% of atypical/malignant meningiomas but not in benign tumors. The most of patients had peritumoral edema, which was clearly seen on FLAIR images. These features were not statistically significant to correctly predict the tumor grades of meningiomas. Specificity of conventional MRI was 73.5%, sensitivity was 62.2%, positive predictive value (PPV) - 79.0%, and negative predictive value (NPV) - 67.6%.

On DWIs (b= 1000) absolute ADC values in benign meningiomas ranged from 0.79 to 0.95x10³ # mm²/s, whereas the NADS ratio ranged from 1.12 to 1.59. In atypical and malignant meningiomas absolute ADC ranged from 0.53 to 1.31x10³ # mm²/s, NADC ranged from 0.82 to 1.55. The mean and SD of absolute intratumoral ADC in benign meningioma was 0.89±0.09x10³ # mm²/s, and in atypical/malignant meningiomas the mean ADC of 0.64±0.12x10³ # mm²/s was significantly lower (p<0.0001). The mean NADS ratio in the atypical/malignant group (0.93±0.18) was also significantly lower than in the benign group (1.29±0.12; p<0.0001). (Table 1) Although absolute ADC values showed considerable overlap, there was no NADC ratio overlap between groups. We found the mean ADC value and NADC ratio were lower in atypical/malignant meningiomas than in benign tumors. (Figure 2) Sensitivity of DWI was 95%, specificity was 80%, PPV - 89%, and negative predictive value (NPV) - 94%.

Table 1. Apparent diffusion coefficient (ADC) and normalized ADC (NADC) values comparison in intracranial meningiomas (x10³ # mm²/s¹ #). Data are the mean ±SD

<table>
<thead>
<tr>
<th>Meningioma</th>
<th>ADS</th>
<th>NADC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benign</td>
<td>0.89±0.09</td>
<td>1.29±0.12</td>
</tr>
<tr>
<td>Atypical/malignant</td>
<td>0.64±0.12</td>
<td>0.93±0.18</td>
</tr>
</tbody>
</table>

The mean maximal rCBV values in the parenchyma of benign meningiomas (7.18±4.12) was higher than that of malignant meningiomas (6.01±3.89). The mean rMTE values in the parenchyma of benign and malignant meningiomas were 1.14±0.23 and 1.24±0.27. The mean maximal rCBV values in the peritumoral edema of benign and malignant meningiomas were 1.07±0.95 and 3.85±1.41, the mean rMTE values in the peritumoral edema of benign and malignant meningiomas were 0.88±0.24 and 1.21±0.31. Sensitivity of PWI was 97%, specificity was 91%, PPV - 85%, and NPV - 92%.
The differences in rCBV and rMTE between benign and malignant meningiomas were not significant (P>0.05) in the parenchyma, but both were significant (p< 0.05) in the peritumoral edema. (Table 2) (Figure 3)

Table 2. Maximal rCBV and corresponding rMTE values of benign and malignant meningiomas in solid portion and peritumoral region. Data are the mean ±SD

<table>
<thead>
<tr>
<th>Meningioma</th>
<th>rCBV</th>
<th></th>
<th>rMTE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parenchyma</td>
<td>Peritumoral</td>
<td>Parenchyma</td>
<td>Peritumoral</td>
</tr>
<tr>
<td>Benign</td>
<td>7.18±4.12</td>
<td>1.07±0.95</td>
<td>1.14±0.23</td>
<td>0.88±0.24</td>
</tr>
<tr>
<td>Malignant</td>
<td>6.01±3.89</td>
<td>3.85±1.41</td>
<td>1.24±0.27</td>
<td>1.21±0.31</td>
</tr>
</tbody>
</table>

Our results showed that a DWI can distinguish benign from atypical/ malignant meningiomas, NADC may be accurate predictor of tumor grade than absolute ADC. Measurement of maximal rCBV and corresponding rMTE values in the peritumoral edema was different in the different tumor grade. DWI and PWI may be useful imaging marker to study meningioma grading and progression.
Conclusion

Diffusion and perfusion MR imaging are useful in the preoperative differentiation between benign and malignant meningiomas.
References


Buetow MP, Buetow PC, Smirniotopoulos JG. Typical, atypical, and misleading features in meningioma. Radiographics 1991;11:1087-106

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