The role of the perfusion and diffusion MR imaging in grading of intracranial gliomas

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Purpose

Gliomas are the most common primary neoplasm of the brain in adults, varying histologically from low grade to high grade [1, 2]. MRI plays a crucial role in the pre-operative assessment of brain gliomas [3, 4]. Despite the fact that conventional MRI with contrast enhancement has led to improved accuracy in the detection and characterization of various brain tumors, the procedure has certain limitations related to the nonspecificity of contrast enhancement, it does not provide a clear-cut differential diagnosis between high- and low-grade gliomas [5, 6]. For this reason, the clinical role of functional MR procedures, such as PWI and DWI has become an important area of investigation [7, 8, 9]. The degree of MR perfusion abnormality reflects the degree of microvasculature, with or without destruction of the blood-brain barrier, whereas the presence of contrast enhancement at conventional MR imaging represents a pathologic alteration in blood-brain barrier, with or without concomitant vascular hyperplasia. Perfusion MR imaging using a relative cerebral blood volume (rCBV) map is particularly sensitive in depicting tumor neovascularization, which is widely used in the differential diagnosis of brain tumors and in pre-operative grading of gliomas [10, 11, 12].

Our aim was to assess the diagnostic value of DWI and PWI in pre-operative grading of gliomas.

Methods and Materials

32 patients (17 women, 15 men; mean age 44 years, age range 26-75 years) underwent conventional, diffusion/perfusion-weighted MRI (DWI/PWI) before surgical resection. 9 low-grade gliomas (WHO Grade I and II) and 23 high grade gliomas (WHO Grade III) were verified histologically. Low grade gliomas consisted of low grade astrocytomas (Grade I, n=4), low grade oligodendrogliomas (Grade II, n=3) and low grade mixed oligoastrocytomas (Grade II, n=2); while high grade gliomas consisted of anaplastic astrocytomas (Grade III, n=14) and anaplastic oligodendrogliomas (Grade III, n=9). Conventional MRI revealed the ordinary signs of tumor. We analyzed both the averaged ADC value and the maximum rCBV ratio between anaplastic gliomas(Grade III) and low-grade gliomas(Grade I, Grade II) 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 maximum rCBV values from the solid portion of the tumor, peritumoral area and contralateral white matter.

The Student t-test was used to determine if there were statistically significant differences in both averaged ADC value and maximum rCBV ratio between anaplastic gliomas and low grade gliomas. A $p$-value of less than 0.05 was considered to indicate statistical significance.

Results

Conventional MRI revealed homogeneous or heterogeneous signal intensity of tumors with clear evidence of central necrosis in all high grade gliomas and some low grade gliomas. The solid tumor tissue exhibited typical hyperintensity on T2 weighted images and hypointense on T1 weighted images (Figure 1). The most of patients had peritumoral edema and mass effect. Eight of twenty three patients with Grade III tumors did not produce significant contrast enhancement. Specificity of conventional MRI was more than 75%.

On DWIs ($b= 1000$) lower ADC values were presented in the solid portions of high grade gliomas (Grade III) - $(0,49\pm 0,10 \times 10^{-3}\text{mm}^2\text{s}^{-1})$, but not in low grade gliomas (Grade I and II) - $(1,12\pm 0,14 \times 10^{-3}\text{mm}^2\text{s}^{-1})$. The difference was significant ($p<0,01$). All ADC values in peritumoral regions were decreased compared with contralateral normal white matter. There was no significant difference between high $(0,71\pm 0,14 \times 10^{-3}\text{mm}^2\text{s}^{-1})$ and low grade gliomas $(0,81\pm 0,09 \times 10^{-3}\text{mm}^2\text{s}^{-1})$ ($p>0,05$). The ADC values showed the higher sensitivity and specificity than conventional MRI (more than 81%). (Table 1)

Table 1. Apparent diffusion coefficient values comparison in intracranial gliomas with contralateral wight matter $(x10^{-3}\text{mm}^2\text{s}^{-1})$. Data are the mean ±SD

<table>
<thead>
<tr>
<th>Grade</th>
<th>Cases</th>
<th>Solid tumor</th>
<th>Peritumoral region</th>
<th>Contralateral WM</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4</td>
<td>1,15 ± 0,17</td>
<td>0,85 ± 0,15</td>
<td>1,45 ± 0,33</td>
</tr>
<tr>
<td>II</td>
<td>5</td>
<td>1,05 ± 0,18</td>
<td>0,76 ± 0,08</td>
<td>1,36 ± 0,31</td>
</tr>
<tr>
<td>III</td>
<td>23</td>
<td>0,49 ± 0,10</td>
<td>0,71 ± 0,14</td>
<td>1,41 ± 0,39</td>
</tr>
</tbody>
</table>

On perfusion MR imaging rCBV maps were inhomogeneous with increases of signal intensity in both solid portion and peritumoral region of high grade gliomas (Figure 2). The signal intensity in the peritumoral region was homogeneous on rCBV map in low grade (Grade I and Grade II) gliomas (Figure 3). High maximum rCBV ratios were
present in both solid portions and peritumoral regions of anaplastic gliomas (Grade III - 4.48±1.87; 3.15±0.52), but not in low-grade (Grade I - 1.16±0.27; 1.36±0.42 and Grade II - 2.45±0.96; 1.59±0.67), with a sensitivity and specificity more than 88% (p<0.01). (Table 2)

Table 2. Maximum relative cerebral blood volume ratio in solid portion and peritumoral region of intracranial gliomas. Data are the mean ±SD

<table>
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Our results showed different ADC values in solid portions of different tumor grades; however the ADC value in peritumoral region is unreliable, no significant difference was found.

Visual grading based on rCBV mapping provided additional information about tumor characteristics. Tumors with lower ADC values in the solid portions and higher rCBV ratios in both solid portions and peritumoral regions are significantly correlated with anaplasia.

Images for this section:
Fig. 1: Figure 1. Grade III astrocytoma. T2 weighted image (a), T1 weighted image with contrast enhancement (b), DWI (b = 1000) (c), Apparent diffusion coefficient (ADC) (d), Relative cerebral blood volume (rCBV) colour map (e), Signal-intensity time-curve (f). Typical hyperintensity on T2 weighted images; peritumoural edema, mass effect and contrast enhancement in the solid portions of tumor were present. On DWIs (b = 1000) restricted diffusion with lower ADC values were present in the solid portion of the tumour with respect to the white matter; rCBV maps were inhomogeneous with various increases of signal intensity in solid portion of tumour.
Fig. 2: Figure 2. Grade III oligoastrocytoma. T2 weighted image (a), T1 weighted image with contrast enhancement (b), DWI (b = 1000) (c), Apparent diffusion coefficient (ADC) (d), Relative cerebral blood volume (rCBV) colour map (e), Signal-intensity time-curve (f). Typical hyperintensity on T2 weighted images, minimal peritumoural edema and no contrast enhancement was present. On DWIs (b = 1000), the signal intensity was hyperintense with respect to the white matter; lower ADC values were present. rCBV maps were inhomogeneous with various increases of signal intensity of tumour.
Fig. 3: Figure 3. Grade II oligoastrocytoma. The tumor reveals typical hyperintensity, peritumoural edema and mass effect on flair images (a), no contrast enhancement was present. The signal intensity in both peritumoural region and solid portion of tumour was homogeneous on rCBV map. (rCBV) colour map (b), Signal-intensity time-curve (c).
Conclusion

Perfusion and diffusion MR imaging adds more information to conventional MRI in the differentiation and grading of brain tumors, therefore they could be integrated in the diagnostic work-up in grading of intracranial gliomas.

References

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