Tumour/normal brain apparent diffusion coefficient value ratios allow for distinguishing common paediatric cerebellar tumours

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Purpose

Excluding brain stem gliomas, the four common pediatric central nervous system tumors (pilocytic astrocytoma, medulloblastoma, ependymoma, and atypical teratoid/rhabdoid tumor) constitute more than 85% of all pediatric cerebellar neoplasms. In this retrospective study, we sought to identify clinically useful tumor/normal brain ADC (apparent diffusion coefficient) value thresholds for distinguishing these four common pediatric cerebellar tumors.

Methods and Materials

Neuro-Oncology database was used to identify eligible patients from January 2001 through April 2010. Patients with the four most common pediatric cerebellar tumors (pilocytic astrocytoma, ependymoma, medulloblastoma, and atypical teratoid/rhabdoid tumor) were included. There were 79 patients (51 male, mean age: 5.90 years, 0.25-18.73) with these diagnoses who had their preoperative MR imaging and surgery performed at our institution. The pathological diagnosis was made according to the latest WHO classification of tumors of the central nervous system.

Imaging and Measurement of ADC Values

The MR examinations were performed at 1.5 Tesla and 3 Tesla scanners (Philips Medical Systems, Best, The Netherlands). Diffusion-weighted imaging (DWI) was performed using a spin echo sequence with b=0, 1000. ADC maps were generated with a monoexponential fit on a voxel-to-voxel basis for all imaging planes. Two reviewers (one pediatric neuroradiologist with 9 years experience and one pediatric radiology fellow) independently measured the ADC values of the tumors and normal brain. The measurements were made at a clinical PACS (picture archival and communications) workstation. The pediatric radiology fellow did not know what the histopathological diagnosis of the tumors. The pediatric neuroradiologist was familiar with some of the cases and knew the histopathological diagnoses. The solid portions of the tumor were sampled. ROIs were drawn on three consecutive images. If the solid tumor was visible on less than three images, non-overlapping regions of interest were drawn, on the images that showed tumor, so that each tumor was sampled from three different regions. The frankly hemorrhagic foci, seen as T1 shortening on the conventional sequences, were excluded. The ADC values of the normal appearing cerebellum and right thalamus were recorded. Tumor/normal cerebellum ADC ratios were calculated.

Statistical analysis
Receiver Operating Characteristic (ROC) analysis was performed using MedCalc Software (Mariakerke, Belgium).

Results

Patient demographics and tumor types are shown in Table 1. The pediatric radiologist sampled larger areas of tumor and normal brain compared with the pediatric radiology fellow (Table 2). The average ADC values of the normal cerebellum were $710.44 \pm 118.61$ and $693.01 \pm 114.26 \times 10^{-6} \text{mm}^2/\text{s}$ measured by the pediatric neuroradiologist and pediatric radiology fellow, respectively. The average ADC values of right thalamus were $789.79 \pm 130.14$ and $769.76 \pm 134.85 \times 10^{-6} \text{mm}^2/\text{s}$ measured by the pediatric neuroradiologist and pediatric radiology fellow, respectively. The measurements performed by the pediatric neuroradiologist and pediatric radiology fellow were concordant (Fig 1A, 1B).

The mean tumor/normal cerebellum brain ADC ratios using measures obtained by the pediatric neuroradiologist and pediatric radiology fellow are given in Table 3.

Using the pediatric neuroradiologist's measurements, a threshold of 1.80 was used to sort PAs from ependymomas with a sensitivity of 93.55% and a specificity of 78.57%. A threshold of 1.25 was used to sort ependymomas from medulloblastomas with a sensitivity of 100% and a specificity of 92.59%.

Using the pediatric radiology fellow's measurements, a threshold of 1.80 sorted JPAs from ependymomas with a sensitivity of 87.10% and a specificity of 85.71%. A threshold of 1.25 sorted ependymomas from medulloblastomas with a sensitivity of 100 and a specificity of 77.78. Medulloblastomas and AT/RTs were not distinguishable neither by the pediatric neuroradiologist's nor by the pediatric radiology fellow's measurements.

Conclusion

Tumors of the posterior fossa constitute a significant fraction of pediatric CNS tumors. Brainstem tumors are relatively easier to characterize due to their location and diffusely infiltrative appearance. In this retrospective study, we intended to calculate clinically useful tumor/normal brain ADC value thresholds with reasonable sensitivity and specificity that can easily be applied into routine clinical practice. We chose to investigate the four most common pediatric cerebellar tumors in our practice because PAs, medulloblastomas, ependymomas and AT/RTs constituted 88.26% (188/213) of the
posterior fossa neoplasms excluding intrinsic brainstem tumors and arachnoid cysts seen at our Neuro-Oncology Department from January 2001 through April 2010.

Rumboldt et al. described utility of the ADC in differentiation of common cerebellar tumors. In this study, all of the 17 PAs had facilitated diffusion with ADC values varying between 1240 and 2090 x 10^{-6} mm^2/s. Although the mean ADC values of PAs and ependymomas were significantly different from each other (1650 ± 270 versus 1100 ± 110 x 10^{-6} mm^2/s, for PAs and ependymomas, respectively); there was some overlap between the ADC values of PAs and ependymomas whose ADC values ranged from 970 to 1290 x 10^{-6} mm^2/s. The tumor / normal brain ADC ratios ranged between 1.62 and 2.99 for PAs and between 1.15 and 1.85 for ependymomas. In this study, there were 8 medulloblastomas whose ADC values were lower than those of PAs and ependymomas with no overlap. The tumor/ normal brain ADC ratios of medulloblastomas ranged from 0.66 to 1.10. The ADC values of the two AT/RTs reported in this study were indistinguishable from those of medulloblastomas.

We purposefully used much larger ROIs compared with the previous reports in order to simulate the clinical practice, because generally, radiologists do not measure the ADC values in a brain tumor, instead they compare it with the adjacent normal appearing brain in order to decide whether the diffusion is restricted, facilitated or normal in the lesion. This was another reason we elected to use the normal appearing cerebellar ADC values, instead of ADC values of the thalamus in our ROC analyses.

Pediatric cerebellar tumors are not uncommon. Even in a clinical practice setting, when used in conjunction with conventional imaging characteristics and patient demographics, tumor / normal brain ADC ratios are very useful tools.

**Images for this section:**

<table>
<thead>
<tr>
<th>Tumor type</th>
<th>n</th>
<th>M/F</th>
<th>mean age, years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilocytic Astrocytoma</td>
<td>31</td>
<td>15/16</td>
<td>7.35 (1.44-18.73)</td>
</tr>
<tr>
<td>Medulloblastoma</td>
<td>27</td>
<td>19/8</td>
<td>6.16 (1.15-14.18)</td>
</tr>
<tr>
<td>Ependymoma</td>
<td>14</td>
<td>13/1</td>
<td>4.61 (0.46-17.18)</td>
</tr>
<tr>
<td>AT/RT</td>
<td>7</td>
<td>4/3</td>
<td>1.06 (0.25-2.29)</td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Fig. 1:** Table 1. Patient demographics and tumor types.

<table>
<thead>
<tr>
<th>ROI Area (cm²) (mean ± sd)</th>
<th>Pediatric Neuroradiologist</th>
<th>Pediatric Radiology Fellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumor</td>
<td>2.88 ± 2.3</td>
<td>1.25 ± 0.33</td>
</tr>
<tr>
<td>Cerebellar</td>
<td>4.37 ± 6.9</td>
<td>1.41 ± 0.2</td>
</tr>
<tr>
<td>Thalamus</td>
<td>3.05 ± 4.1</td>
<td>1.46 ± 1.1</td>
</tr>
</tbody>
</table>

*Table 2. Area measurements for regions of interest by study participants*

**Fig. 2:** Table 2. Areas of regions of interested drawn by the 2 study participants.

<table>
<thead>
<tr>
<th>Tumor type</th>
<th>Pediatric Neuroradiologist</th>
<th>Pediatric Radiology Fellow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tumor:Cerebellum</td>
<td>Tumor:Thalamus</td>
</tr>
<tr>
<td>PA</td>
<td>2.36</td>
<td>2.13</td>
</tr>
<tr>
<td>Medulloblastoma</td>
<td>0.95</td>
<td>0.85</td>
</tr>
<tr>
<td>Ependymoma</td>
<td>1.64</td>
<td>1.48</td>
</tr>
<tr>
<td>AT/RT</td>
<td>0.83</td>
<td>0.72</td>
</tr>
</tbody>
</table>

*Table 3. ADC Ratio of Tumor: Normal Brain*

**Fig. 3:** Table 3. Mean tumor / normal brain ADC ratios calculated for the pediatric neuroradiologist and pediatric radiology fellow.
**Fig. 4:** Figure 1A. Box plots depicting ADC values for each of four common pediatric cerebellar tumors as measured by the pediatric neuroradiologist. ADC values for normal cerebellum and thalamus are shown for comparison.

**Fig. 5:** Figure 1B. Box plots depicting ADC values for each of four common pediatric cerebellar tumors as measured by pediatric radiology fellow. ADC values for normal cerebellum and thalamus are shown for comparison.
References


10.1016/j.neurad.2007.01.010


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