Volumetric Assessment of Corticospinal Tract Infiltration by Astrocytoma Using Diffusion Tensor Tractography

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Aims and objectives

The aim of the study is to assess volumetric Corticospinal Tract infiltration by Astrocytoma using Diffusion Tensor Tractography.
Methods and materials

Patient population: The study was done between October 2012 and December 2013 where 33 patients with intracranial space-occupying lesions underwent surgery. Patients were informed about study objectives and hazards and written consent were obtained. Ethical committee approved the study. Among them, nine patients had lesions near the corticospinal tract, on the basis of conventional MR imaging findings, and these nine patients (five men, four women; mean age, 43 years; age range, 29 - 62 years) were included in our study. Six patients were ASTROCYTOMA WHOII. All the patients were admitted to our institution for neurosurgery, and routine preoperative evaluations were performed, which included 1-T MR imaging. Full neurological examinations were performed (Table 1), and consequently all patients in this series underwent preoperative diffusion tensor MRI (DT-MRI) as part of surgical planning for image-guided tumor resection, in addition to preoperative anatomic T2-weighted fast spin echo (T2FSE), and volumetric T1-weighted MRI (3DSPGR). All patients in this series underwent image-guided tumor resection. Histopathologic examination of the resected tumor tissue confirmed the diagnosis of low- or high-grade glioma in each case.

Image Analysis
The 3D-Slicer software package [1]-[5] was used for image registration and processing. This is a modular software package with image registration, segmentation and DT-MRI processing capabilities. First, the anatomic (3D-SPGR and T2-FSE) and the DT-MRI scans were rigidly registered, using a maximization of mutual information (MI) algorithm. This algorithm is fully implemented in the 3D-Slicer software package, and it is known to provide robust and accurate results [6] [7]. Manual adjustments were made where necessary, using as reference anatomic landmarks such as the anterior and posterior commissures, lateral ventricles, and corpus callosum. Each tumor was manually segmented (outlined) from the anatomic T2-FSE scans using the 3D-Slicer and a computer mouse. According to the literature, among anatomic MRI modalities, T2-weighted images appear to reflect the tumor extent more closely, although occult tumor can be found even beyond the region of increased T2-signal in some gliomas [8]-[12]. The tumor volume was computed from the segmented area and voxel size, using the 3D-Slicer software. In the next step, the white matter structure from DT-MRI was visualized. First, fractional anisotropy maps were generated in each case, using the 3D-Slicer software. Next, we obtained both a 2D-visualization [13] and a 3D-tractography in each patient. For the 3D-tractography, we used the algorithm described by Westin et al. [14], which is fully implemented in the 3D-Slicer package. In order to calculate the trajectory of fiber tracts, this algorithm takes into account fractional anisotropy, as well as the angle between the primary eigenvector within a voxel and the
equivalent vector in the neighboring voxels. In order to selectively visualize each fiber tract expected to be in close spatial relationship with the tumor (based on anatomic MRI), we defined seed points, from which the tractography was initialized: ventral brainstem for reconstructing the corticospinal tract, the white matter region adjacent to the lateral geniculate body for the optic radiation, the temporal lobe stem for tracking the uncinate fasciculus, etc. The 3D-tractography results were compared with the corresponding 2D-visualization maps and manually corrected, in order to ensure that artifacts were removed. Finally, the tumor regions intersecting white matter tracts were manually segmented and their volume calculated in the same manner as the total tumor volume.

Table 1. Patient population and tumor characteristics.

<table>
<thead>
<tr>
<th>Case</th>
<th>Sex</th>
<th>Age (yrs.)</th>
<th>Tumor location</th>
<th>Histopathology</th>
<th>Eloquent cortical No. and white matter areas affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>32</td>
<td>L frontal</td>
<td>Astrocytoma WHO II</td>
<td>SMA, motor strip, motor pathway</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>34</td>
<td>R temporal</td>
<td>Oligodendroglioma WHO II</td>
<td>Wernicke's area, optic radiation</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>41</td>
<td>L temporal-parietal</td>
<td>Astrocytoma WHO II</td>
<td>SMA, motor pathway</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>61</td>
<td>R frontal medial</td>
<td>Anaplastic Astrocytoma</td>
<td>Motor strip, motor pathway</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>38</td>
<td>L fronto-temporal</td>
<td>Astrocytoma WHO II</td>
<td>Motor strip, motor pathway</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>45</td>
<td>L frontal</td>
<td>Anaplastic strocytoma</td>
<td>Motor and sensory strip, motor pathway, arcuate (superior longitudinal) fasciculus</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>46</td>
<td>R occipital</td>
<td>Oligodendroglioma WHO II</td>
<td>Optic radiation</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>34</td>
<td>L insular</td>
<td>Ganglioglioma</td>
<td>Motor pathway</td>
</tr>
</tbody>
</table>

Careful analysis of the table showed that 66.6% (4/6) Astrocytoma tumors are Frontal in position and one case is frontotemporal and the last one is temporal-parietal.
Images for this section:

**Fig. 1:** Left Insular Astrocytoma in a 33 years old male.

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Fig. 2: Left Insular Astrocytoma in a 33 years old male. Tractography shows infiltration of the CST.

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Fig. 3: Left Insular Astrocytoma in a 33 years old male. Tractography shows infiltration of the CST.

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Results

From the 9 cases of tumors in relation to corticospinal tract, we identified that white matter tracts were infiltrated by 6 Astrocytoma tumors. With respect to Table 2 the median tumor volume (±standard deviation) in our patient population was 33 ± 26.82 ml. The median tumor volume (±standard deviation) infiltrating white matter fiber tracts were 4.15 ± 9.23 ml. The median fraction of tumor volume infiltrating white matter fiber tracts was 26.3% ± 10.1%.

Careful analysis of the table showed that there is a difference in tumor behaviour apart from its gross volume.

As in case number 4 where Tumor volume is 9.3 ml however 28% of its volume is infiltrating the tract (Figure 1, 2 and 3) and if compared to case number 9 where tumor volume is 91.8 ml (larger than case 4) yet only 24.6% are infiltrating the tract. Also case number 6 has highest fraction of tumor volume infiltrating the corticospinal tract. So the fraction of tumor volume infiltration is not directly proportional to the tumor size. This is an interesting point needs further study.

Table 2. Volumetric assessment of white matter infiltration.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Tumor volume (ml)</th>
<th>Tumor volume infiltrating fiber tracts (ml)</th>
<th>Fraction of Tumor volume infiltrating fiber tracts (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33.7</td>
<td>4.8</td>
<td>14.2</td>
</tr>
<tr>
<td>2</td>
<td>51.3</td>
<td>13.7</td>
<td>26.7</td>
</tr>
<tr>
<td>3</td>
<td>32.3</td>
<td>2.4</td>
<td>7.4</td>
</tr>
<tr>
<td>4</td>
<td>9.3</td>
<td>2.6</td>
<td>28.0</td>
</tr>
<tr>
<td>5</td>
<td>28.3</td>
<td>3.5</td>
<td>12.4</td>
</tr>
<tr>
<td>6</td>
<td>62.6</td>
<td>23.1</td>
<td>36.9</td>
</tr>
<tr>
<td>7</td>
<td>9.2</td>
<td>2.6</td>
<td>28.3</td>
</tr>
<tr>
<td>8</td>
<td>13.0</td>
<td>2.0</td>
<td>15.4</td>
</tr>
<tr>
<td>9</td>
<td>91.8</td>
<td>22.6</td>
<td>24.6</td>
</tr>
</tbody>
</table>
Conclusion

Diffusion tensor MR Tractography is a reliable preoperative assessment tool since it detects extensive white matter infiltration by Astrocytoma irrespective of brain tumors volume.

Recommendations: Prospective large population studies are required to clarify how infiltration relates to tumor location.
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References


