The value of white matter tractography by diffusion tensor imaging in altering a neurosurgeon's operative plan

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Introduction

• Diffusion tensor imaging (DTI) with tractography is the only available tool that shows the disruption of the white matter (WM) tracts based on fractional anisotropy changes and fiber reconstructions in patients with brain tumors.

• WM tract involvement adjacent to a brain tumor can be classified as intact, deviated, displaced, interrupted, or destroyed.

• Preservation of the superior longitudinal fasciculus (SLF) in patients undergoing glioma resection is correlated to preservation of speech.

• Preservation of the inferior fronto-occipital fasciculus (IFOF) is correlated to preservation of the optic radiation (OR).

• Pyramidal tracts and superior thalamic radiations (STR) represent the eloquent motor and sensory WM tracts accordingly.

• We investigated the clinical significance of DTI WM tractography review by neurosurgeons during the preoperative assessment in identifying and preserving the eloquent WM tracts.
Methods

- A retrospective review of 18 patients with supra-tentorial brain tumors adjacent to eloquent WM tracts who underwent tractography by DTI as part of their preoperative assessment.

- DTI results were reported by two individual radiologists in the form of three different categories, and 3 discrete groups regarding the type of eloquent WM implementation (Table).

- A blinded prospective behavioral study followed, where four neurosurgeons reviewed the preoperative images at two different times a) MRI without DTI, followed by b) MRI with DTI; they provided two best estimates of the DTI group types and described their planned surgical approach.

<table>
<thead>
<tr>
<th>Category of Eloquent White Matter Tract Involvement</th>
<th>Diffusion Tensor Imaging Group Type</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor and sensory pathways (corticospinal tracts, corticopontine tracts, superior thalamic radiation), N = 15</td>
<td>Group 1</td>
<td>3 (20)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>8 (53)</td>
</tr>
<tr>
<td></td>
<td>Group 3</td>
<td>4 (27)</td>
</tr>
<tr>
<td>Language pathway (left superior longitudinal fasciculus), N = 7</td>
<td>Group 1</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>5 (71)</td>
</tr>
<tr>
<td></td>
<td>Group 3</td>
<td>2 (29)</td>
</tr>
<tr>
<td>Optic pathway (inferior fronto-occipital fasciculus, inferior longitudinal fasciculus, posterior thalamic radiations), N = 15</td>
<td>Group 1</td>
<td>7 (47)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>4 (27)</td>
</tr>
<tr>
<td></td>
<td>Group 3</td>
<td>4 (27)</td>
</tr>
</tbody>
</table>

Group 1, intact eloquent white matter bundles (normal anisotropy, normal location); group 2, deviated (normal anisotropy, abnormal location) and/or displaced (low anisotropy, normal orientation) white matter bundles; group 3, interrupted (low anisotropy, abnormal orientation) and/or destroyed (zero anisotropy, tract unidentifiable) white matter bundles.
Results

• DTI Group 1 consisted of patients at a low risk for injury with intact eloquent WM tracts (normal anisotropy, normal location)

• DTI Group 2 included patients at a high risk for intraoperative injury with deviated (normal anisotropy, abnormal location) and/or displaced bundles (low anisotropy, normal orientation)

• DTI Group 3 consisted of patients with established WM tract injuries who presented with interrupted bundles (low anisotropy, abnormal orientation) and/or destroyed (zero anisotropy, tract unidentifiable) tracts
Representative DTI color map of a patient with a right temporoparietal glioblastoma multiforme (GBM)

A) WM bundles retain their anisotropy along with normal anatomic locations (Group 1 DTI)

B) The right SLF is deviated medially (arrow), retaining its normal anisotropy (group 2 DTI)

C) The CST and STR are displaced medially, but retain their normal craniocaudal (blue) orientation (group 2 DTI)

D) The mass interrupts (arrow) the ILF (group 3 DTI)

Results

• 15 patients (11 male and 4 female) with mean age of 58.3 years
• After review of only the MRI without DTI, the neurosurgeons accurately estimated the correct DTI groups in 53% of the motor/sensory cases, 60% of the optic pathway category cases, and 57% of the language category cases overall
• The neurosurgeons predicted the DTI group 3 in the motor/sensory category and the optic pathway category only in 25% of the times ($P < 0.01$).
• After review of the DTI the neurosurgeons did not drastically alter their surgical management regarding the extent of the tumor resection or type of surgical approach (transcortical, transsulcal parafascicular, other)
• DTI was reported to be a useful tool by the neurosurgeons 68% of the time
• DTI helped surgeons to feel more comfortable about proceeding with gross total resection (13%), and identifying the IFOF and ILF paths (27%)
• DTI is especially valuable in identifying and preserving the optic radiations (OR)
Discussion

• DTI tractography can be a promising tool for preoperatively estimating the degree of radicality to be achieved by surgical resection

• The preoperative DTI review in our series showed that surgeons had difficulty in recognizing the DTI group 3 cases in the motor/sensory and optic pathway categories

• In the absence of DTI tractography, neurosurgeons have the false assumption that motor and optic pathway bundles are not interrupted by the tumor, which could lead them toward conservatism in their surgical approach

• Surgeons tend to formulate their surgical resection plan mostly based on preoperative MRI with contrast, using DTI as an adjunct
Summary Points

- Despite its inability to drastically alter our operative strategy, DTI tractography remains an important noninvasive tool in preoperative assessment.

- DTI is especially valuable for identifying patients with interrupted motor and optic pathway tracts.

- DTI provides neurosurgeons with additional safety in recognizing OR, which could lead toward a more aggressive extent of tumor resection, especially in the subpopulation where OR has been destroyed by the tumor.