Diffusion Tensor Imaging Tractography Indications

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Diffusion Tensor Imaging Tractography is a noninvasive technique that enables the visualization and quantification of white matter tracts within the brain. It is extensively used in preoperative planning for brain tumors, epilepsy surgery, and functional neurosurgical procedures such as deep brain stimulation. Significant advancements have been made in imaging acquisition, fiber direction estimation, and tracking methods, resulting in considerable improvements in tractography accuracy. The technique enables the mapping of functionally critical pathways around surgical sites to avoid permanent functional disability. When the limitations are adequately acknowledged and considered, tractography can serve as a valuable tool to safeguard critical white matter tracts and provide insight regarding changes in normal white matter and structural connectivity of the whole brain beyond local lesions. In functional neurosurgical procedures such as deep brain stimulation, it plays a significant role in optimizing stimulation sites and parameters to maximize therapeutic efficacy and can be used as a direct target for therapy. These insights can aid in patient risk stratification and prognosis [1)]

A article of Tae et al. in 2018 summarizes the clinical role of DTI in various disease processes such as amyotrophic lateral sclerosis, multiple sclerosis, Parkinson's disease, Alzheimer's dementia, epilepsy, ischemic stroke, stroke with motor or language impairment, traumatic brain injury, spinal cord injury, and depression. Valuable DTI postprocessing tools for clinical research are also introduced [2)]

Preoperative fiber tracking (FT) enables visualization of white matter pathways. However, the intraoperative accuracy of preoperative image registration is reduced due to brain shift. Intraoperative FT is currently considered the standard of anatomical accuracy, while intraoperative imaging can also be used to correct and update preoperative data by Intraoperative MRI-based elastic fusion (IBEF). However, the use of intraoperative tractography is restricted due to the need for additional acquisition of diffusion imaging in addition to scanner limitations, quality factors, and setup time. Since IBEF enables compensation for brain shift and updating of preoperative FT, the aim of this study was to compare intraoperative FT with IBEF of preoperative FT.

Preoperative MRI (pMRI) and ioMRI, both including diffusion tensor imaging (DTI) data, were acquired between February and November 2018. Anatomy-based DTI FT of the corticospinal tract (CST) and the arcuate fascicle (AF) was reconstructed at various fractional anisotropy (FA) values on pMRI and ioMRI, respectively. The intraoperative DTI FT, as a baseline tractography, was fused with original preoperative FT and IBEF-compensated FT, processes referred to as rigid fusion (RF) and elastic fusion (EF), respectively. The spatial overlap index (Dice coefficient [DICE]) and distances of surface points (average surface distance [ASD]) of fused FT before and after IBEF were analyzed and compared in operated and nonoperated hemispheres.

Seventeen patients with supratentorial brain tumors were analyzed. On the operated hemisphere, the overlap index of pre- and intraoperative FT of the CST by DICE significantly increased by 0.09 maximally after IBEF. A significant decrease by 0.5 mm maximally in the fused FT presented by ASD was observed. Similar improvements were found in IBEF-compensated FT, for which AF tractography on the tumor hemispheres increased by 0.03 maximally in DICE and decreased by 1.0 mm in ASD.

Preoperative tractography after IBEF is comparable to intraoperative tractography and can be a reliable alternative to intraoperative FT [3).

Diffusion tensor imaging for brainstem cavernous malformation

Diffusion tensor imaging for brainstem cavernous malformation

Diffusion tensor imaging for brain tumor resection

Diffusion tensor imaging for brain tumor resection.

Diffusion tensor imaging for degenerative cervical myelopathy

see Diffusion tensor imaging for degenerative cervical myelopathy.

Pediatric stroke

Plasticity of the developing motor tracts is a contributor to recovery of motor function after pediatric stroke. The mechanism of these plastic changes may be functional and/or structural in nature.

In a case of a 3-year-old girl demonstrating reorganization of the pyramidal tracts after an extensive left MCA territory stroke secondary to head trauma. Reorganization is characterized using serial diffusion tensor imaging (DTI) of the pyramidal tracts which contain the CST.

Imaging shows decreased ipsi-lesional fractional anisotropy (FA) suggestive of Wallerian degeneration and increased contralesional FA.

These results point to plastic reorganization of the pyramidal tract post-stroke and the utility of DTI in recognizing these changes [4].

Pulsed arterial spin labeling, DTI, and MR spectroscopy are useful for predicting glioma grade. Additionally, the parameters obtained on DTI and MR spectroscopy closely correlated with the proliferative potential of gliomas [5].

Intracranial meningiomas

For predicting the consistency of intracranial meningiomas.

Traumatic brain injury

Diffusion Tensor Imaging Tractography for traumatic brain injury.

Hydrocephalus

A retrospective DTI study demonstrated significant WM abnormalities in infants with hydrocephalus in both the corpus callosum and internal capsule. The results also showed evidence that the impact of hydrocephalus on WM was different in the corpus callosum and internal capsule [6].

A study provides initial evidence of DTI's sensitivity to detect subtle WM changes associated with performance improvements in response to a 6-week occupational therapy (OT) intervention in children with surgically treated hydrocephalus (HCP) [7].

DTI may be used for the diagnosis and differentiation of idiopathic normal pressure hydrocephalus (iNPH) from other neurodegenerative diseases with similar imaging findings and clinical symptoms and signs. The goal of a study was to identify and analyze recently published series on the use of DTI as a diagnostic tool. Moreover, Siasios et al., also explored the utility of DTI in identifying patients with iNPH who could be managed by surgical intervention.

The authors performed a literature search of the PubMed database by using any possible combinations of the following terms: “Alzheimer's disease,” “brain,” “cerebrospinal fluid,” “CSF,” "diffusion tensor imaging," "DTI," "hydrocephalus," "idiopathic," "magnetic resonance imaging," "normal pressure," "Parkinson's disease," and "shunting." Moreover, all reference lists from the retrieved articles were reviewed to identify any additional pertinent articles.

The literature search retrieved 19 studies in which DTI was used for the identification and differentiation of iNPH from other neurodegenerative diseases. The DTI protocols involved different approaches, such as region of interest (ROI) methods, tract-based spatial statistics, voxel-based analysis, and delta-ADC analysis. The most studied anatomical regions were the periventricular WM areas, such as the internal capsule (IC), the corticospinal tract (CST), and the corpus callosum (CC). Patients with iNPH had significantly higher MD in the periventricular WM areas of the CST and the CC than had healthy controls. In addition, FA and ADCs were significantly higher in the CST of iNPH patients than in any other patients with other neurodegenerative diseases. Gait abnormalities of iNPH patients were statistically significantly and negatively correlated with FA in the CST and the minor forceps. Fractional anisotropy had a sensitivity of 94% and a specificity of 80% for diagnosing iNPH. Furthermore, FA and MD values in the CST, the IC, the anterior thalamic region, the fornix, and the hippocampus regions could help differentiate iNPH from Alzheimer or Parkinson's disease. Interestingly, CSF drainage or ventriculoperitoneal shunting significantly modified FA and ADCs in iNPH patients whose condition clinically responded to these maneuvers.

Measurements of FA and MD significantly contribute to the detection of axonal loss and gliosis in the periventricular WM areas in patients with iNPH. Diffusion tensor imaging may also represent a valuable noninvasive method for differentiating iNPH from other neurodegenerative diseases. Moreover, DTI can detect dynamic changes in the WM tracts after lumbar drainage or shunting procedures and could help identify iNPH patients who may benefit from surgical intervention [8].

Diffusion tensor imaging for trigeminal neuralgia

see Diffusion tensor imaging for trigeminal neuralgia

A number of studies have investigated tractography-guided brain tumour surgery over the past years and reported good clinical results [9].

DTI-based tractography is an increasingly important tool for planning brain surgery in patients suffering from brain tumours. However, there is an ongoing debate which tracking approaches yield the most valid results. Especially the use of functional localizer data such as navigated transcranial magnetic stimulation (nTMS) or functional magnetic resonance imaging (fMRI) seem to improve fibre tracking data in conditions where anatomical landmarks are less informative due to tumour-induced distortions of the gyral anatomy.

Deep brain stimulation

Diffusion Tensor Imaging Tractography for Deep brain stimulation

Diffusion Tensor Imaging Tractography for facial nerve preservation

see Diffusion Tensor Imaging Tractography for facial nerve preservation.

1)

Kamagata K, Andica C, Uchida W, Takabayashi K, Saito Y, Lukies M, Hagiwara A, Fujita S, Akashi T, Wada A, Hori M, Kamiya K, Zalesky A, Aoki S. Advancements in Diffusion MRI Tractography for Neurosurgery. Invest Radiol. 2023 Sep 15. doi: 10.1097/RLI.0000000000001015. Epub ahead of print. PMID: 37707839.

2)

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3)

Zhang W, Ille S, Schwendner M, Wiestler B, Meyer B, Krieg SM. Tracking motor and language eloquent white matter pathways with intraoperative fiber tracking versus preoperative tractography adjusted by intraoperative MRI-based elastic fusion. J Neurosurg. 2022 Feb 25:1-10. doi: 10.3171/2021.12.JNS212106. Epub ahead of print. PMID: 35213839.

4)

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5)

Fudaba H, Shimomura T, Abe T, Matsuta H, Momii Y, Sugita K, Ooba H, Kamida T, Hikawa T, Fujiki M. Comparison of Multiple Parameters Obtained on 3T Pulsed Arterial Spin-Labeling, Diffusion Tensor Imaging, and MRS and the Ki-67 Labeling Index in Evaluating Glioma Grading. AJNR Am J Neuroradiol. 2014 Jul 3. [Epub ahead of print] PubMed PMID: 24994829.

6)

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7)

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8)

Siasios I, Kapsalaki EZ, Fountas KN, Fotiadou A, Dorsch A, Vakharia K, Pollina J, Dimopoulos V. The role of diffusion tensor imaging and fractional anisotropy in the evaluation of patients with idiopathic normal pressure hydrocephalus: a literature review. Neurosurg Focus. 2016 Sep;41(3):E12. doi: 10.3171/2016.6.FOCUS16192. PubMed PMID: 27581308.

9)

Wu J.S., Zhou L.F., Tang W.J. Clinical evaluation and follow-up outcome of diffusion tensor imaging-based functional neuronavigation: a prospective, controlled study in patients with gliomas involving pyramidal tracts. Neurosurgery. 2007;61(5):935–948.