

## Magnetic resonance diffusion tensor imaging and fiber-tracking diffusion tensor tractography in the management of spinal astrocytomas

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### Abstract

Some specially imaging of magnetic resonance imaging, the diffusion-weighted imaging (DWI), the diffusion tensor imaging and fractional anisotropy (FA), are useful to described, detect, and map the extent of spinal cord lesions. FA measurements may are used to predicting the outcome of patients who have spinal cord lesions. Fiber tracking enable to visualizing the integrity of white matter tracts surrounding some lesions, and this information could be used to formulating a differential diagnosis and planning biopsies or resection. In this article, we will describe the current uses for DWI and fiber tracking and speculate on others in which we believe these techniques will be useful in the future.

**Key words:** Fiber tracking diffusion tensor imaging; Surgery; Magnetic resonance diffusion tensor imaging; Intramedullary astrocytomas; Spinal cord tumors; Radiology

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**Core tip:** Intramedullary high grade astocytomas are rare tumors of spinal cord. Current surgical treatment involves loss of neurological function. The possibility to visualize directly the white matter tracts in the spine, with the applications of specific sequences of magnetic resonance imaging (diffusion-weighted imaging, diffusion tensor imaging and fractional anisotropy) allows neurosurgeons to better guide the surgical approach and resection, with the goal of neurological function preservation.

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## INTRODUCTION

Some specially imaging of magnetic resonance imaging (MRI), diffusion-weighted imaging (DWI), diffusion tensor imaging (DTI) and fractional anisotropy (FA), are useful to described, detect, and map the extent of spinal cord lesions<sup>[1-3]</sup>. FA measurements may are used to predicting the outcome of patients who have spinal cord lesions. Fiber tracking enable to visualizing the integrity of white matter tracts surrounding some lesions, and this information could be used to formulating a differential diagnosis and planning biopsies or resection. In this article, we describe the current use for DWI and fiber tracking and speculate on others in which we believe these techniques will be useful in the future.

Intrinsic tumors of the spinal cord are more or less 10% of all central nervous system tumors<sup>[4,5]</sup>, are rare neoplasms, and astrocytomas are the most frequent type<sup>[6,7]</sup>. MRI techniques provide only anatomical information while DTI, a form of diffusion-weighted MRI, gave us information about assesses of physiological water directionality and motion, providing images of white matter tracts of the central nervous system<sup>[8-10]</sup>. The possibility to visualize white matter tracts in the spine enables neurosurgeons to better guide their surgical approach and resection. Intramedullary high grade astrocytoma has a minor incidence compared to all other tumor and its outcome is burdened with important consequences for the patients<sup>[11]</sup>. Certainly many of the neurological consequences depend on the early diagnosis; for this reason operation is recommended as soon as possible. Actually DTI is used for the design of surgical excision of brain tumors, but the capability of the DTI to display faithfully secondary alterations to the white matter tracts caused by the lesion current studies, allow us to hypothesize that (whit literature supporting)<sup>[12-14]</sup> use of DTI is also possible for spinal surgery to prepare preoperative planning for tumor resection, preoperative diagnosis, and postoperative outcomes and this is one of the key point of the future therapy of intrinsic tumors of the spinal cord<sup>[15-17]</sup>, however further studies are needed about this technique to understand and more studies are necessary for this technology to establish standardized protocols.

## TECHNIQUE DESCRIPTION AND USE OF DTI-DWI-FT

In organized tissues, water diffusion is anisotropic and the quantitative description of this anisotropy is possible

with DTI, that is a modification of diffusion imaging which can display vectors corresponding to the direction of water molecular movement, which has become a useful tool in the clinic trial of spinal pathologies, including tumors<sup>[18-20]</sup>. DTI sequences with computation of FA are more sensitive in determining the presence of intrinsic abnormalities in spinal cord compression due to the presence, for example, of a tumor<sup>[21,22]</sup>. Can be used in different ways both the study of the directional anisotropy, using DTI, or the removal of this anisotropy, that can be measured by tensor trace, all this information are used to compile mapping of the fibers through an algorithms<sup>[23,24]</sup>. Anyhow these techniques are affected by artifacts that depend on the movement, the noise and this make it difficult to diagnose with exactness the extension and moreover the quality of the DWI, in term of resolution, is poor to image structures as small the spinal cord and its internal features, DTI have a better characterization of white fibers and their possible displacement by the tumor and the reconstruction of 3D images of white matter tracts use new tracking algorithms. So as to employ the indicated encouraging technology, it is necessary to understand the basis of the anisotropy contrast in DTI and the restrictions imposed by using a macroscopic technique to visualize restrictions. In our opinion, also based on the review of the recent literature in the field, DTI and fiber tracking (FT) are used to describe tumors and to detect their limbs. Is also possible to envisage a histological diagnosis if you know that FA values are similar for astrocytomas, ependymomas and metastases but are different for hemangioblastomas<sup>[25-27]</sup>; in particular the lowest FA values are seen in metastases, and the highest are seen in hemangioblastomas. Unfortunately the algorithm alone is unable to distinguish between extracellular edema and destroyed white matter tracts by tumor cell involvement. Based on these observations using FA maps, the edema that surrounding lesion may be separated from the tumor due to lower values in the former. FT may show fibers that are destroyed or displaced by the tumor. This could be important to estimate highly infiltrative tumors and to identify their margins before surgery resection<sup>[2,28,29]</sup>.

FT showed the main posterior white matter tracts, such as posterior lemniscal tracts and posterolateral corticospinal tracts. In patients with spinal neoplasms, 3D FT reconstructions of the spinal cord involvement, showed the tumor limbs matching those seen on the MRI T2-weighted imaging if are solid tumors with dislocated or wrecked spinal cord fibers tumors unlike metastases that are localized and tend not to infiltrate<sup>[21,30,31]</sup>. Regrettably FT does not consider these margins in patients with cystic tumors. FT algorithm is based on the principal diffusion direction method, because in the spinal cord the white matter fibers have a craniocaudal orientation and are anisotropic. This algorithm is used to reconstruct fiber tracts by using FA values; where there is no interruption (linear diffusion), FA values are fixed at certain value. In this case the FT algorithm is unable to link voxels inside the same tract

due to the increased isotropic diffusivity of extracellular water; This aspect is contrary to solid-state lesions, in which the FA values are different (usually elevated). The decrease of the FA thresholding value identifies tracts among edema or tumor cells and it seems to be unrelated to the multidirectionality of the tracts<sup>[32,33]</sup>. The increase of the FA thresholding value reduced the regular anatomic tracts that were seen on normal white matter anatomy. Totally of these information recommend that FT could be applied to visualize the bent white matter tracts in the solid state astrocytomas, but absence of sensitivity in cases of presence of cystic and/or vasogenic edema. Further studies are mandatory to establish these conclusions.

## USE IN SPINAL NEURONAVIGATION

The possibility to combination of anatomical data, contained in MRI T<sub>1</sub>-weighted images, and the trajectories of the pyramidal tract, allowed the demonstration of its position related to the lesion, both during operation planning and surgery<sup>[13]</sup>. Based on the reconstructed pyramidal tract, surgeon may compares to various alternatives in surgical approaches, permitting to perform a surgical plan reducing pyramidal tract damages. In fact neuronavigation should be use in two different ways: (1) to understand the extension of an intrinsic spinal lesions that must be remove; and (2) to help in estimating tumor removal limits during surgery.

In the future, to permit the routinary use of FT system in neurosurgical and neuro-radiological procedure, the workflow could be change. The DTI sequence could be acquired together with all already existing MRI protocols. For this reasons is mandatory that a neuro-radiologist or a computer scientist always perform FT, and the images combined by anatomical data and fiber tract trajectories, were sent back to the picture achieving and communication systems (PACS) central archive or directly to neurosurgical planning and navigation systems. Also is essential that the MR imaging protocol is executed at least few day before the surgical procedure in order to have a more recent radiological status of the lesion; the average time necessary to process the images for neuro-planning/neuro-navigation is not a inaccessible constituent and the FT system could be, beyond all expectation, included in routinary clinical use without any delays in the clinical-therapeutic timing.

## CONCLUSION

DTI-based fiber tracking can certainly detects: (1) white matter fibers tracts; (2) presence of anatomopathological alterations; and (3) deviations and involvement of white matter tracts by spinal tumors. Moreover it gives to a minimally invasive neurosurgery. DTI sequences that can visualize the white matter tracks *in vivo* and under normal clinical conditions, are useful for fiber tracking if the tracking algorithm is strong and

can solve ambiguities<sup>[10]</sup>. Advancement of near-tumoral anisotropy contrast acquisition is another significant issue to permit a increasingly faithful identification of white matter tracts in this crucial area and to discriminate among edematous reaction that might resolve successive surgical operation. Moreover it is useful to detect white matter tumor occupation or destruction, which has significant implications on neurosurgical strategies. Further investigation is still necessary and an available integrated FT software tool may be included into the PACS infrastructure of a clinic and medical staff trained to use it. Thus because the diffusion of this technology is still very limited and users could be also trained and motivated to export the resulting data to the neuronavigation and neurosurgical planning systems and use them in their routine<sup>[9,11]</sup>.

The intramedullary high grade astrocytomas have got an infiltrating nature, that make a total surgical removed impossible without an important loss of neurological function. The application of DTI-based fiber tracking, for diagnosis and neuronavigation, should be used in the clinical routine for the management of intramedullary high grade astrocytomas. Thus because in this way the surgical intervention could be performed to obtain a more safer histological diagnosis and tumor resection, without worsening of neurological function.

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