**Name of Journal: *World Journal of Clinical Cases***

**ESPS Manuscript NO: 18354**

**Manuscript Type:** **Editorial**

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

Landi A *et al*. MRI fiber-tracking in spinal astrocytomas

**Alessandro Landi, Valeria Palmarini, Alessandro D’Elia, Maurizio Salvati, Nicola Marotta, Antonio Santoro, Roberto Delfini**

**Alessandro Landi, Valeria Palmarini, Alessandro D’Elia, Maurizio Salvati, Nicola Marotta, Antonio Santoro, Roberto Delfini,** Department of Neurology and Psychiatry, Division of Neurosurgery, University of Rome “Sapienza”, 00181 Rome, Italy

**Author contributions:** Landi A and Palmarini V designed work and wrote the manuscript; D’Elia A, Marotta N researched the bibliography; Salvati M, Santoro A and Delfini R have supervised and corrected the manuscript.

**Conflict-of-interest statement:** The author has no conflict of interests.

**Open-Access:** This article is an open-access article which was selected byan in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

**Correspondence to: Alessandro Landi, MD, PhD,** Department of Neurology and Psychiatry, Division of Neurosurgery, University of Rome Sapienza, Viale del Policlinico 155, 00181 Rome, Italy. [dott.alessandro.landi@gmail.com](mailto:dott.alessandro.landi@gmail.com)

**Telephone:** +39-064-9979105

**Fax:** +39-064-9979105

**Received:** April 17, 2015

**Peer-review started:** April 18, 2015

**First decision:** July 6, 2015

**Revised:** October 14, 2015

**Accepted:** December 1, 2015

**Article in press:**

**Published online:**

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

© **The Author(s) 2015**. Published by Baishideng Publishing Group Inc. All rights reserved.

**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.

Landi A, Palmarini V, D’Elia A, Salvati M, Marotta N, Santoro A, Delfini R. Magnetic resonance diffusion tensor imaging and fiber-tracking diffusion tensor imaging in the management of spinal astrocytomas. *World J Clin Cases* 2015; In press

**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[1-3]. 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[4,5], are rare neoplasms, and astrocytomas are the most frequent type[6,7]. 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[8-10] . 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[11]. 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)[12-14]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[15-17], 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[18-20]. 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[21,22]. 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[23,24]. 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 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[25-27]; 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[2,29,29].

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 RMN 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[21,30,31]. 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[32,33]. The increase of the FA thresholding value reduced the regular anatomic tracts that were seen on normal white matter anatomy. Totally of these information reccomend 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 T1-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[13]. 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 extention of an intrinsic spinal lesions that must be remove; (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 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 costituent 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 anatomo-pathological alterations, (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[10]. 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[9,11].

The intramedullary high grade astocytomas 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 hystological diagnosis and tumor resection, without worsening of neurological function.

**REFERENCES**

1 **Schwartz ED**, Duda J, Shumsky JS, Cooper ET, Gee J. Spinal cord diffusion tensor imaging and fiber tracking can identify white matter tract disruption and glial scar orientation following lateral funiculotomy. *J Neurotrauma* 2005; **22**: 1388-1398 [PMID: 16379577 DOI: 10.1089/neu.2005.22.1388]

2 **Ducreux D**, Lepeintre JF, Fillard P, Loureiro C, Tadié M, Lasjaunias P. MR diffusion tensor imaging and fiber tracking in 5 spinal cord astrocytomas. *AJNR Am J Neuroradiol* 2006; **27**: 214-216 [PMID: 16418387]

3 **Raco A**, Piccirilli M, Landi A, Lenzi J, Delfini R, Cantore G. High-grade intramedullary astrocytomas: 30 years' experience at the Neurosurgery Department of the University of Rome "Sapienza". *J Neurosurg Spine* 2010; **12**: 144-153 [PMID: 20121348]

4 **Ducreux D**, Fillard P, Facon D, Ozanne A, Lepeintre JF, Renoux J, Tadié M, Lasjaunias P. Diffusion tensor magnetic resonance imaging and fiber tracking in spinal cord lesions: current and future indications. *Neuroimaging Clin N Am* 2007; **17**: 137-147 [PMID: 17493544 DOI: 10.1016/j.nic.2006.11.005]

5 **El Maati AAA,** Chalabi N. Diffusion tensor tractography as a supplementary tool to conventional MRI for evaluating patients with myelopathy. *EJRNM* 2014; **45:** 1223-1231 [DOI: 10.1016/j.ejrnm.2014.08.004]

6 **Dellani PR**, Glaser M, Wille PR, Vucurevic G, Stadie A, Bauermann T, Tropine A, Perneczky A, von Wangenheim A, Stoeter P. White matter fiber tracking computation based on diffusion tensor imaging for clinical applications. *J Digit Imaging* 2007; **20**: 88-97 [PMID: 16946990 DOI: 10.1007/s10278-006-0773-7]

7 **Schonberg T**, Pianka P, Hendler T, Pasternak O, Assaf Y. Characterization of displaced white matter by brain tumors using combined DTI and fMRI. *Neuroimage* 2006; **30**: 1100-1111 [PMID: 16427322 DOI: 10.1016/j.neuroimage.2005.11.015]

8 **Ozanne A**, Krings T, Facon D, Fillard P, Dumas JL, Alvarez H, Ducreux D, Lasjaunias P. MR diffusion tensor imaging and fiber tracking in spinal cord arteriovenous malformations: a preliminary study. *AJNR Am J Neuroradiol* 2007; **28**: 1271-1279 [PMID: 17698527 DOI: 10.3174/ajnr.A0541]

9 **Summers P**, Staempfli P, Jaermann T, Kwiecinski S, Kollias S. A preliminary study of the effects of trigger timing on diffusion tensor imaging of the human spinal cord. *AJNR Am J Neuroradiol* 2006; **27**: 1952-1961 [PMID: 17032874]

10 **Liu X**, Tian W, Kolar B, Hu R, Huang Y, Huang J, Ekholm S. Advanced MR diffusion tensor imaging and perfusion weighted imaging of intramedullary tumors and tumor like lesions in the cervicomedullary junction region and the cervical spinal cord. *J Neurooncol* 2014; **116**: 559-566 [PMID: 24374994 DOI: 10.1007/s11060-013-1323-z]

11 **Vargas MI**, Delavelle J, Jlassi H, Rilliet B, Viallon M, Becker CD, Lövblad KO. Clinical applications of diffusion tensor tractography of the spinal cord. *Neuroradiology* 2008; **50**: 25-29 [PMID: 17909776]

12 **Houten JK**, Cooper PR. Spinal cord astrocytomas: presentation, management and outcome. *J Neurooncol* 2000; **47**: 219-224 [PMID: 11016738 DOI: 10.1023/A: 1006466422143]

**13 Huddart R**, Traish D, Ashley S, Moore A, Brada M. Management of spinal astrocytoma with conservative surgery and radiotherapy. *Br J Neurosurg* 1993; **7**: 473-481 [PMID: 8267886 DOI: 10.3109/02688699308995069]

14 **Facon D**, Ozanne A, Fillard P, Lepeintre JF, Tournoux-Facon C, Ducreux D. MR diffusion tensor imaging and fiber tracking in spinal cord compression. *AJNR Am J Neuroradiol* 2005; **26**: 1587-1594 [PMID: 15956535]

15 **Vadapalli RMSV,** Reshma Reddy R, Roychowdhury A, Mulukutla RRD, Hyderabad/IN, Sturbridge MA/US. Fiber tracking and tractography of spinal cord: Potential clinical spplications - A pictorial essay. ECR 2010; C-2576

16 **Krings T**, Reinges MH, Thiex R, Gilsbach JM, Thron A. Functional and diffusion-weighted magnetic resonance images of space-occupying lesions affecting the motor system: imaging the motor cortex and pyramidal tracts. *J Neurosurg* 2001; **95**: 816-824 [PMID: 11702872 DOI: 10.3171/jns.2001.95.5.0816]

17 **Landi A.** Future directions in the treatment of Malignant spinal cord tumors. *J Spine Neurosurg* 2013; S1 [DOI: 10.4172/2325-9701.S1-e001]

18 **Reinges MH**, Schoth F, Coenen VA, Krings T. Imaging of postthalamic visual fiber tracts by anisotropic diffusion weighted MRI and diffusion tensor imaging: principles and applications. *Eur J Radiol* 2004; **49**: 91-104 [PMID: 14746933 DOI: 10.1016/j.ejrad.2003.09.004]

19 **McCormick PC**, Torres R, Post KD, Stein BM. Intramedullary ependymoma of the spinal cord. *J Neurosurg* 1990; **72**: 523-532 [PMID: 2319309 DOI: 10.3171/jns.1990.72.4.0523]

20 **Basser PJ**, Pierpaoli C. A simplified method to measure the diffusion tensor from seven MR images. *Magn Reson Med* 1998; **39**: 928-934 [PMID: 9621916 DOI: 10.1002/mrm.1910390610]

21 **Westin CF**, Maier SE, Mamata H, Nabavi A, Jolesz FA, Kikinis R. Processing and visualization for diffusion tensor MRI. *Med Image Anal* 2002; **6**: 93-108 [PMID: 12044998 DOI: 10.1016/S1361-8415(02)00053-1]

22 **Werring DJ**, Toosy AT, Clark CA, Parker GJ, Barker GJ, Miller DH, Thompson AJ. Diffusion tensor imaging can detect and quantify corticospinal tract degeneration after stroke. *J Neurol Neurosurg Psychiatry* 2000; **69**: 269-272 [PMID: 10896709 DOI: 10.1136/jnnp.69.2.269]

23 **Voss HU**, Watts R, Uluğ AM, Ballon D. Fiber tracking in the cervical spine and inferior brain regions with reversed gradient diffusion tensor imaging. *Magn Reson Imaging* 2006; **24**: 231-239 [PMID: 16563951 DOI: 10.1016/j.mri.2005.12.007]

24 **Wang FN**, Huang TY, Lin FH, Chuang TC, Chen NK, Chung HW, Chen CY, Kwong KK. PROPELLER EPI: an MRI technique suitable for diffusion tensor imaging at high field strength with reduced geometric distortions. *Magn Reson Med* 2005; **54**: 1232-1240 [PMID: 16206142 DOI: 10.1002/mrm.20677]

25 **Ellis CM**, Simmons A, Jones DK, Bland J, Dawson JM, Horsfield MA, Williams SC, Leigh PN. Diffusion tensor MRI assesses corticospinal tract damage in ALS. *Neurology* 1999; **53**: 1051-1058 [PMID: 10496265 DOI: 10.1212/WNL.53.5.1051]

26 **Horsfield MA**, Jones DK. Applications of diffusion-weighted and diffusion tensor MRI to white matter diseases - a review. *NMR Biomed* 2002; **15**: 570-577 [PMID: 12489103 DOI: 10.1002/nbm.787]

27 **Basser JB.** Fiber-tractography via diffusion tensor MRI. In Proceedings of International Society for Magnetic Resonance in Medicine, Sydney, 1998: 1226

28 **Conturo TE**, Lori NF, Cull TS, Akbudak E, Snyder AZ, Shimony JS, McKinstry RC, Burton H, Raichle ME. Tracking neuronal fiber pathways in the living human brain. *Proc Natl Acad Sci USA* 1999; **96**: 10422-10427 [PMID: 10468624]

29 **Wheeler-Kingshott CA**, Hickman SJ, Parker GJ, Ciccarelli O, Symms MR, Miller DH, Barker GJ. Investigating cervical spinal cord structure using axial diffusion tensor imaging. *Neuroimage* 2002; **16**: 93-102 [PMID: 11969321 DOI: 10.1006/nimg.2001.1022]

30 **Xu D**, Mori S, Solaiyappan M, van Zijl PC, Davatzikos C. A framework for callosal fiber distribution analysis. *Neuroimage* 2002; **17**: 1131-1143 [PMID: 12414255 DOI: 10.1006/nimg.2002.1285]

31 **Mori S**, Crain BJ, Chacko VP, van Zijl PC. Three-dimensional tracking of axonal projections in the brain by magnetic resonance imaging. *Ann Neurol* 1999; **45**: 265-269 [PMID: 9989633 DOI: 10.1002/1531-8249(199902)45: 2<265: : AID-ANA21>3.0.CO; 2-3]

32 **Jones DK**, Simmons A, Williams SC, Horsfield MA. Non-invasive assessment of axonal fiber connectivity in the human brain via diffusion tensor MRI. *Magn Reson Med* 1999; **42**: 37-41 [PMID: 10398948 DOI: 10.1002/(SICI)1522-2594(199907)42: 1<37: : AID-MRM7>3.0.CO; 2-O]

33 **Schmidt AT**, Martin RB, Ozturk A, Kates WR, Wharam MD, Mahone EM, Horska A. Neuroimaging and neuropsychological follow-up study in a pediatric brain tumor patient treated with surgery and radiation. *Neurocase* 2010; **16**: 74-90 [PMID: 20391187 DOI: 10.1080/13554790903329133]

**P- Reviewer:** Alimehmeti R **S- Editor:** Song XX **L- Editor:** **E- Editor:**