European Journal of Radiology 85 (2016) 2275–2280

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

# Spinal diffusion tensor tractography for differentiation of intramedullary tumor-suspected lesions

K. Egger[a,*,1], M. Hohenhaus[b,1], V. Van Velthoven[c], S. Heil[a], H. Urbach[a]

[a] Department of Neuroradiology, University Medical Center Freiburg, Breisacher Straße 64, 79106 Freiburg, Germany
[b] Department of Neurosurgery, University Medical Center Freiburg, Breisacher Straße 64, 79106 Freiburg, Germany
[c] Department of Neurosurgery, UZ Brussel, Laarbeeklaan 101, 1090 Brussel, Belgium

ARTICLE INFO

*Article history:*
Received 4 June 2016
Received in revised form
22 September 2016
Accepted 15 October 2016

*Keywords:*
MRI
Spinal
Intramedullary
DTI
Tractography

ABSTRACT

*Background and purpose:* Primary MRI diagnosis of spinal intramedullary tumor-suspected lesions can be challenging and often requires spinal biopsy or resection with a substantial risk of neurological deficits. We evaluated whether Diffusion Tensor Imaging (DTI) tractography can facilitate the differential diagnosis.

*Materials and methods:* Twenty-five consecutive patients with an intramedullary tumor-suspected lesion considered for spinal surgery were studied with a Diffusion-weighted multi-shot read out segmented EPI sequence (RESOLVE). White matter tracts ("streamlines") were calculated using the FACT algorithm and visually co-registered to a T2-weighted 3D sequence. The fused images were assessed concerning spinal streamline appearance as normal, displaced or terminated. Definite diagnosis was verified by histological analysis or further clinical work-up.

*Results:* All patients with normal appearing streamlines (n = 6) showed an acute inflammatory demyelinating pathology in the further clinical work-up. In 10 patients streamline displacing lesions were found from which 5 patients underwent a surgical treatment with histologically confirmed low-grade tumors like ependymomas and pilocytic astrocytomas. In nine patients streamlines were terminated, from which 6 patients received a histology proven diagnoses with a more heterogenous spectrum (3 cases of high grade tumor, 1 case of low grade tumor with intralesional hemorrhage and 2 cases with gliosis but no tumor cells).

*Conclusion:* Using multi-shot DTI spinal tractography acute inflammatory lesions can be differentiated from other tumorous intramedullary lesions. The entity diagnosis of spinal tumors seems to be more challenging, primarily due to the variety of factors like invasivity, expansion or intralesional hemorrhage.


## 1. Introduction

Magnetic resonance imaging (MRI) is the gold standard for the non-invasive diagnosis of spinal intramedullary lesions because of the highest lesion perceptibility and local resolution [1,2]. The primarily radiologic diagnosis is important for guidance to surgical treatment or further noninvasive diagnostics [3]. Intramedullary tumors are rare with only 5–10% of all spinal tumors [2,4]. Unfortunately, in up to 16% of suspected intramedullary tumors the proven histologic diagnosis after biopsy is a demyelinating lesion. [5–8] The discrimination of those tumor-mimicking lesions is crucial because of the complete different non-invasive therapy strategy [1,3].

Diffusion Tensor Imaging (DTI), a specific MRI technique for analyzing molecular water motion, can help to evaluate the integrity of white matter tracts and associated tissue pathologies [9]. Based on the calculated diffusion tensor white matter tracts can be reconstructed, representing the path of preferently water diffusion. However, it is important to know that the resulting reconstructed white-matter tracts do not represent real axonal tracts. Therefore, we prefer using the term "streamlines" to describe the tractography outcome. DTI has been applied in ischemic, traumatic and inflammatory spinal lesions, but results are limited concerning neoplastic

*Abbreviations:* MRI, magnetic resonance imaging; DTI, diffusion tensor imaging; EPI, echo planar imaging; TE, echo time; TR, repetition time; FOV, field of view; TA, acquisition time; nSL, normal streamlines; dSL, displaced streamlines; tSL, terminated streamlines.

* Corresponding author at: Department of Neuroradiology, University Medical Center Freiburg, Breisacher Str. 64, 79106 Freiburg, Germany.
*E-mail address:* karl.egger@uniklinik-freiburg.de (K. Egger).
[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.ejrad.2016.10.018
0720-048X/

pathologies [9–11]. One previous DTI study focused on the treatment of intramedullary tumors by dividing the spinal lesions in 3 subtypes: type 1 with no streamlines entering the lesion was considered as resectable without major neurological deficits; type 2 lesions mostly not containing streamlines and type 3 mostly containing streamlines were considered as not resectable, due to potential neurological deficits [12]. All these previous spinal DTI studies used single-shot diffusion-weighted echo planar imaging (EPI).

Using conventional single-shot EPI, the DTI quality is potentially limited by susceptibility artifacts, T2*-blurring and low signal-to-noise ratio (SNR). Susceptibility artefacts are typically induced at interfaces between structures with different susceptibility properties, such as bone and tissue, which may cause major imaging problems especially in the spinal cord. Another challenge is physiological-related motion due to respiration, heart-beat, and cerebrospinal fluid pulsation. All three limitations can be minimized by using a sequence with shorter data sampling time, which for example can be achieved by readout-segmentation [13]. To further improve image quality, the multi-shot readout-segmented diffusion weighted sequence can be combined with parallel imaging to further reduce susceptibility artifacts and shorten the echo-time [14]. And finally, to avoid possible misinterpretation due to image distortion an additional reversed-gradient technique can be applied [15].

Aim of this study was to evaluate the diagnostic potential of a commercially available readout-segmented diffusion-tensor EPI tractography in patients with spinal intramedullary tumor-suspected lesions.

## 2. Methods

### 2.1. Patient selection

Twenty-six consecutive patients with a spinal intramedullary lesion were included in this prospective study. The study was approved by the local ethics committee and all patients gave informed consent. All patients were scanned on a 3T MRI scanner (Magnetom Trio or Prisma, Siemens, Erlangen, Germany) using a conventional spine coil for reception.

### 2.2. MRI protocol

In addition to the standard spine MRI protocol including sagittal and transversal T2-weighted and pre- and post-contrast T1-weighted sequences, DTI was performed in transversal acquisition using the commercially available DTI "RESOLVE" (Readout Segmentation Of Long Variable Echo-trains) sequence with 49 slices, 2 mm slice thickness, TR 7000 ms, TE1 77 ms, TE2 103 ms, FOV $220 \times 220\,mm^2$, Matrix $110 \times 110$, with a resulting resolution of $2 \times 2 \times 2$ mm, PAT GRAPPA 2, b-values 0 and 1000 s/mm2, diffusion directions 20, and TA 12:38 min [14] An additional sagittal T2-weighted SPACE sequence was acquired for providing an anatomical reference image.

### 2.3. MRI post-processing

DTI images were checked for artefacts by an experienced neuroradiologist (E.K.). Tractography was performed using the Siemens "syngo.via" workstation including an additional visual registration of the DTI data with the according reference image. Post-processing included the projection of the spinal streamlines on the co-registered 3D anatomical T2-weighted SPACE images and reconstruction of 2D-images in transversal, coronal and sagittal planes and finally export of the fused 2D images to the local PACS system. The total time needed for the whole procedure was about five minutes.

### 2.4. DTI tractography evaluation

For tractography evaluation we established a simple 3-point scale, based on the appearance of the streamlines in relation to the intramedullary lesion. Normal streamlines (nSL) was defined as normal appearing SL running through the lesion. Displaced streamlines (dSL) was defined as streamlines mostly being displaced by the intramedullary lesion. And finally, terminated streamlines (tSL) was defined as streamlines mostly being terminated in the area of the intramedullary lesion.

Images were rated independently by 1 radiology resident with several years of experience in MRI interpretation (H.S.) and 1 experienced neuroradiologist (E.K.). Both raters were blinded for the final diagnosis. For evaluation the spinal streamlines were superimposed on the T2-weighted 3D anatomical image. No clinical information or other imaging parameters like contrast enhancement were given.

### 2.5. Statistic evaluation

Interrater reliability was tested by computing the Intraclass Correlation Coefficient (ICC) with a two-way mixed model using SPSS 21 software (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corporation).

## 3. Results

In total 26 patients underwent spinal MRI (median age 46.5 years, range from 2 to 79 years, 12 male) (see Table 1). One patient interrupted the examination before finishing DTI due to claustrophobia and was therefore excluded (see Table 1—patient no. 4).

All patients with a nSL type lesion (n = 6) showed an acute inflammatory demyelinating pathology in the further clinical work-up (see Table 1 and Fig. 1).

In 10 patients a dSL type lesion was found (see Table 1 and Fig. 2). Five patients underwent surgical treatment and got therefore a histological proven diagnosis (3 ependymomas WHO°II, 2 pilocytic astrocytomas WHO°I). Five patients had no histological analysis, from which 1 patient showed a hemangioblastoma as part of a pre-existing von-Hippel-Lindau syndrome and in 4 patients the conclusion of the interdisciplinary tumor board was MRI follow-up (2 with MRI proven stable disease and 2 with actually still pending follow-up imaging).

In 9 patients a tSL type lesion was revealed (see Table 1 and Fig. 3). Six patients underwent surgery with following histological work-up (1 oligodendrogliom WHO°III, 1 anaplastic astrocytoma WHO°III, 2 reactive gliosis without any tumor tissue, 1 plexiform neurofibroma WHO°I, and 1 ependymoma WHO°II with intralesional hemorrhage). The spinal lymphoma was confirmed liquor diagnostic and one patient had a spinal metastasis based on a cerebral multifocal anaplastic astrocytoma WHO°III. The remaining 2 patients were treated conservatively with MRI follow-up showing stable disease.

The interrater agreement was very good (ICC = 0.98 with a 95% confidence interval 0.96–0.99). Only one ependymoma was rated differently (reader 1: dSL type versus reader 2: tSL type) (see Table 1—patient 17). Following consensus reading revealed tSL grading.

## 4. Discussion

We applied a multi-shot readout-segmented EPI diffusion-weighted sequence [14] to a consecutive group of 26 patients