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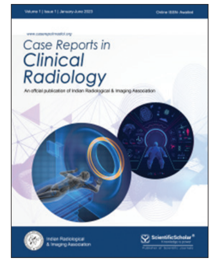

Case Series

Diffusion tensor imaging in evaluation of intradural spinal tumors – A case series

Suryansh Arora[1], Shibani Mehra[1], Umesh Garga[2]

[1]Department of Radiodiagnosis, Atal Bihari Vajpayee Institute of Medical Sciences and Dr. Ram Manohar Lohia Hospital, New Delhi, [2]Department of Radiodiagnosis, Saraswati Institute of Medical Sciences, Hapur, Uttar Pradesh, India.

***Corresponding author:**
Suryansh Arora,
Department of Radiodiagnosis,
Atal Bihari Vajpayee Institute of
Medical Sciences and Dr. Ram
Manohar Lohia Hospital,
New Delhi, India.

drsuryansharora@gmail.com

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ABSTRACT

Diffusion tensor imaging (DTI) is an advanced magnetic resonance imaging (MRI) technique which utilizes diffusion measurements in multiple directions to provide information regarding tissue structure by parameters such as fractional anisotropy (FA) and apparent diffusion coefficient along with generation of fiber tractography maps. We investigated DTI using single shot echo planar imaging in 20 diffusion directions on 3T MRI in nine patients diagnosed with intradural spinal tumors and found significant reduWction in FA value within the lesion compared to FA value at normal cord. Tractography maps generated by DTI were useful in differentiating intramedullary from extramedullary location of tumor. Tractography also provided useful information regarding tract infiltration or displacement in cases of intramedullary neoplasms. Thus, DTI proved helpful in classification, characterization, and treatment planning of intradural spinal tumors.

Keywords: Spinal tumors, Diffusion tensor imaging, Astrocytoma, Ependymoma, Intradural spinal tumor

INTRODUCTION

Spinal tumors are classified based on anatomic location including extradural, intradural extramedullary, and intramedullary tumors. Although extradural tumors are the most common lesions, intradural tumors due to close relation with spinal cord leads to significant morbidity and mortality.[1] Intradural extramedullary tumors include lesions arising from dura, arachnoid, and nerves, while intramedullary tumors arise most commonly from glial cells in the spinal cord. Although magnetic resonance imaging (MRI) is the investigation of choice of assessment of spine and spinal cord pathologies, magnetic resonance (MR) imaging of spinal cord can be a challenging task as the width of spinal cord is only 1 cm in diameter even though it traverses the vertebral column extending from craniovertebral junction to L1 vertebrae. The multiple interfaces including bone-cerebrospinal fluid (CSF) and spinal cord-CSF, motion from adjacent lungs, and heart in thoracic region lead to artifacts such as motion artifacts, truncation artifacts, and CSF pulsation artifacts if the acquisition protocols are not optimized.[2] Due to the limitations in conventional MRI, advanced sequences such as diffusion tensor imaging (DTI), MR angiography, susceptibility weighted imaging, and MR spectroscopy have been applied to characterize the spinal cord lesions. DTI utilizes the diffusion of water molecules to provide information regarding tissue structure. Using diffusion measurements in multiple directions, a 3×3 matrix is obtained (called diffusion tensor) which is further computed to obtain a diffusion ellipsoid. The data obtained in DTI are used to calculate parameters including apparent diffusion coefficient (ADC), axial diffusivity, radial diffusivity, and fractional anisotropy (FA).[3] DTI has a definite role in evaluation of degenerative myelopathy, spinal cord injury, demyelinating disorders, and spinal neoplasms.[4]

CASE SERIES

We performed DTI on nine patients with clinical suspicion of intradural spinal tumor on 3T Siemens Magnetom Skyra MRI. Along with routine MRI sequences, axial DTI sequence was acquired using single shot echo planar imaging with 20 diffusion directions, with b values – 0.1000 s/mm^2, slice thickness – 3 mm, distance factor – 0, and field of view – 220 × 100 mm. Diffusion tensor data were post-processed using Siemens Neuro 3D software. DTI parameters including FA and ADC values were computed along with generation of color coded tractography maps.

Mean age of the study population was 25.14 years with age range from 17 to 34 years. Five patients were found to have intramedullary neoplasm, while four were diagnosed with extramedullary intradural spinal lesions [Table 1].

Marked reduction in FA value was noted in all cases, with mean FA value at lesion – 0.21 ± 0.08 compared to mean FA value in the normal cord – 0.62 ± 0.07. Mean ADC value was found to be higher within the lesion (1.42 ± 0.27 × 10^3 mm^2/s) compared to within the normal cord (1.02 ± 0.1 × 10^3 mm^2/s).

First patient was a 20-year-old male who presented with the right upper limb weakness for last 5 years. MRI revealed eccentric long segment intramedullary mass lesion in cervical spinal cord with hemorrhagic areas demonstrating patchy nodular enhancement. Polar cyst was present at the inferior aspect of the lesion. Perilesional edema was noted in the inferior aspect of the lesion. Marked reduction of FA value was noted on DTI (0.1 ± 0.02). Fiber tractography revealed non-visualization of tracts in right hemicord indicating tract infiltration [Figure 1]. Imaging diagnosis of infiltrating spinal cord neoplasm was made based on tractography. The patient underwent surgical biopsy, and a histopathological diagnosis of spinal cord astrocytoma was confirmed.

Second patient was a 28-year-old female patient presenting with loss of sensory sensation in bilateral lower limbs for 1 year. MRI revealed a centrally placed intramedullary non-enhancing mass lesion in cervical spinal cord with cord expansion [Figure 2]. Imaging diagnosis of spinal ependymoma was made. DTI revealed splaying of tracts toward the periphery with no evidence of infiltration of tracts. Reduction of FA value (FA – 0.32 ± 0.02) and increase in ADC value (ADC- 1.42 ± 0.08) was noted in mass lesion compared to normal cord.

Similarly, we demonstrated infiltration of tracts on tractography in another case of spinal astrocytoma in a 30-year-old male patient and splaying of tracts in two cases of ependymoma, one in cervical and other in dorsal spine.

In one patient, a well-defined elongated intradural cystic lesion (following CSF signal intensity on all sequences) causing marked compression and thinning of spinal cord was identified. The MR characteristics enabled diagnosis of spinal arachnoid cyst. Tractography was able to identify thinning of cervical spinal cord at level of extramedullary lesion with compression of ipsilateral tracts [Figure 3].

Based on MRI appearance of a broad-based intradural extramedullary lesion extending into neural foramen at C4-C5 level, showing isointense signal on T1WI, heterogeneous hyperintense signal on T2WI and homogeneous intense post-contrast enhancement, nerve sheath tumor was diagnosed in one patient. On tractography, intradural location of the tumor was well delineated, and the tumor was seen compressing the cord.

In two patients, we identified intradural extramedullary lesion showing intermediate signal on T2WI and homogeneous intense post-contrast enhancement with dural thickening and enhancement which was diagnosed as spinal meningioma, one in cervical spine and other in dorsal

Table 1: Diagnosis with DTI parameters in cases of Intradural spinal tumors.

S. No.	Age (yrs.)	Intramedullary/ Extramedullary	Diagnosis	Lesion level	FA at lesion	FA at normal cord	ADC at lesion (×10^3 mm^2/s)	ADC at normal (×10^3 mm^2/s)
1	20	Intramedullary	Astrocytoma	C1-C7	0.1±0.02	0.49±0.05	1.6±0.1	1.2±0.04
2	28	Intramedullary	Ependymoma	C4-D1	0.32±0.02	0.58±0.06	1.42±0.08	0.9±0.1
3	34	Intramedullary	Ependymoma	C5-D2	0.29±0.02	0.65±0.02	1.63±0.1	1.03±0.07
4	30	Intramedullary	Astrocytoma	C3-D1	0.21±0.03	0.55±0.05	1.71±0.12	1.12±0.05
5	38	Intramedullary	Ependymoma	D1-D4	0.33±0.02	0.49±0.05	1.81±0.1	1.15±0.05
6	25	Extramedullary	Nerve sheath tumor	C4-C5	0.27±0.04	0.62±0.02	1.59±0.08	0.91±0.07
7	24	Extramedullary	Meningioma	D2-D4	0.14±0.01	0.71±0.02	0.90±0.01	1.02±0.02
8	17	Extramedullary	Arachnoid cyst	C5-C6	0.12±0.04	0.69±0.05	1.6±0.1	1.1±0.07
9	28	Extramedullary	Meningioma	C4-C6	0.24±0.04	0.64±0.03	1.2±0.04	1.0±0.01

DTI: Diffusion tensor imaging, FA: Fractional anisotropy, ADC: Apparent diffusion coefficient

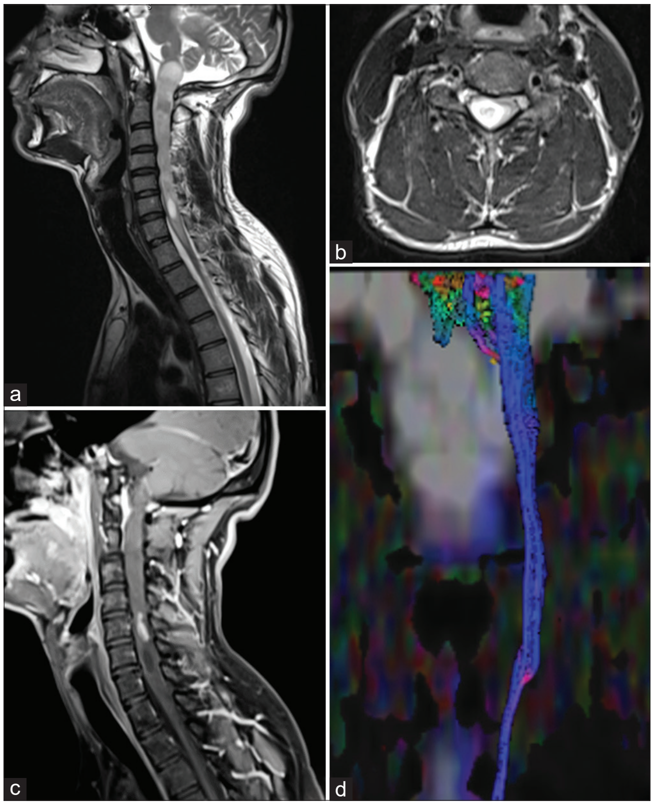

Figure 1: (a and b) Sagittal and axial T2WI shows long segment eccentric lesion in cervical spinal cord with heterogeneous hyperintense signal causing cord expansion. (c) Patchy areas of enhancement are noted on post-contrast images. (d) Tractography shows non-visualization of tracts on right side, representing infiltration of spinal cord tracts. (FA = 0.1 ± 0.02). FA: Fractional anisotropy

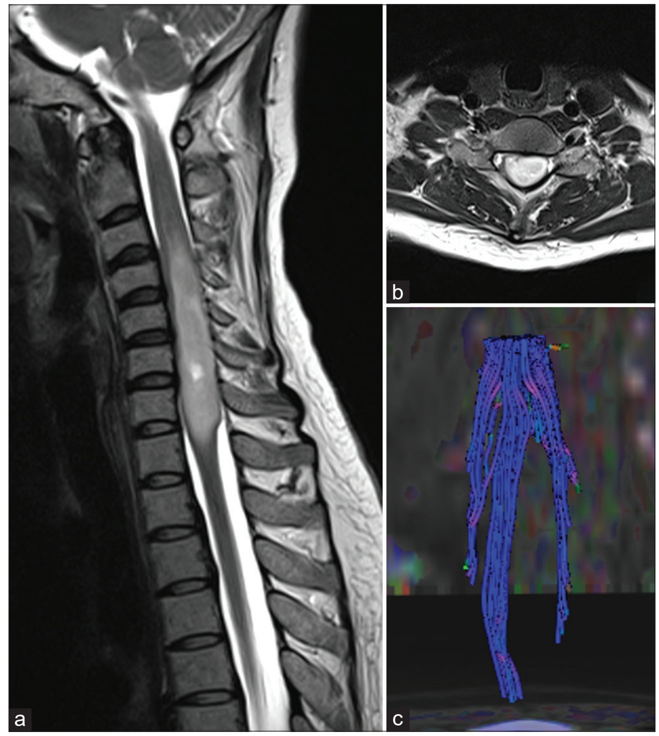

Figure 2: (a and b) Sagittal and axial T2WI shows central hyperintense lesion at C2-C7 level causing cord expansion. No evidence of enhancement was noted on post-contrast images. (c) Tractography shows splaying of white matter tracts to periphery. No evidence of infiltration was noted on tractography (FA = 0.29 ± 0.02) diagnosis – spinal Ependymoma. FA: Fractional anisotropy.

spine. Tractography proved useful to define the intradural extramedullary location of these masses differentiating them from intramedullary tumors by demonstrating compression and splaying of peripheral spinal cord tracts [Figure 4].

Distinguishing between intramedullary and extramedullary location of spinal lesions by tractography maps was noted as a major advantage of DTI.

DISCUSSION

Intradural spinal tumors are characterized using conventional MRI sequences by delineation of anatomic compartment, and assessment of their morphological characteristics, for example, cystic or solid content, intralesional and perilesional hemorrhage, post-contrast enhancement, and perilesional edema.

DTI is an advanced MR sequence which utilizes diffusion gradients in multiple directions to provide microscopic information regarding water motion in tissues which are useful in deciphering anatomic information about white matter tracts. DTI further enables characterization of intradural spinal tumors. Quantitative parameters such as FA and ADC demonstrate cellularity of the tumor while color-coded fiber tractography maps demonstrate location and effect of these masses on the rest of cord and tracts.[5]

It has been found that among DTI parameters, FA has the strongest evidence of utility in clinical pathologies of spinal cord.[6] We found significant reduction in FA value within the masses compared to FA levels in normal cord in all cases.

Tractography was able to differentiate infiltrating from non-infiltrating masses of spinal cord in cases of intramedullary spinal neoplasms. Non-visualization of tracts indicating destruction of tracts was seen on tractography in infiltrating neoplasm. On the other hand, splaying of tracts was seen in non-infiltrating neoplasms.

FA value was also noted to be lower in infiltrative neoplasm – astrocytomas (mean FA = 0.15) compared to non-infiltrative neoplasms – Ependymomas (mean FA = 0.31). Maj *et al.*, in their study, concluded reduction in FA values in infiltrative neoplasms (mean FA at tumor margin – 0.304) compared to non-infiltrative neoplasms (mean FA at tumor margin – 0.399). FA value indicates integrity of spinal cord

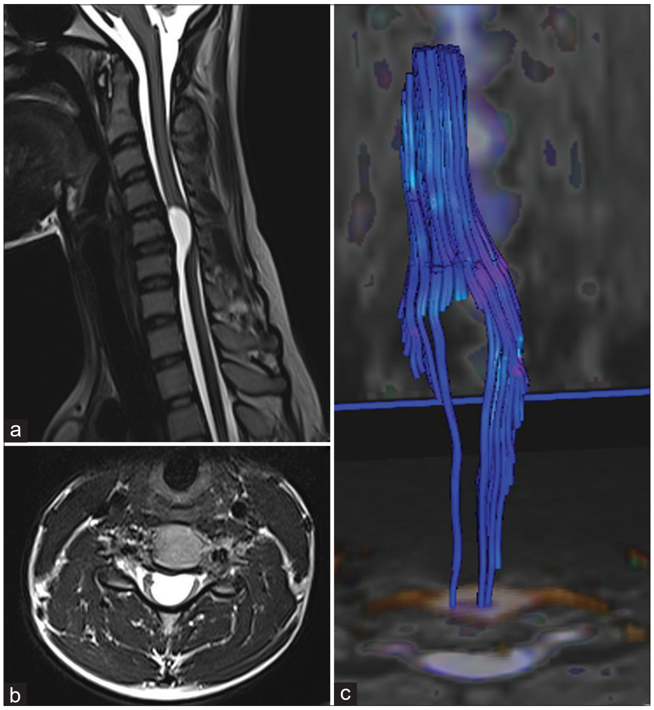

Figure 3: (a and b) Sagittal and axial T2WI shows extramedullary intradural lesion with CSF signal intensity at C5-C6 vertebral level causing compression of adjacent spinal cord. Diagnosis – spinal arachnoid cyst. (c) Tractography image shows splaying of white matter tracts toward periphery with no evidence of infiltration of tracts.

tracts, and thus, the value is found to be lower where there is infiltration of tracts by a mass.[7]

Spinal astrocytomas are infiltrative tumors, regardless of the WHO grade and are associated with poor surgical outcome with gross total resection rarely accomplished. The management in cases of astrocytomas consists of maximum safe surgical resection or biopsy followed by radiotherapy in selected cases. Spinal ependymomas are usually low grade (the WHO grade 1 or 2), with the WHO grade 3 reported only in a few cases. Due to their non-infiltrative nature, complete surgical resection if associated with good overall survival and low recurrence.[8]

Since determination of histology of these tumors is possible only after surgical treatment, imaging plays an important role in characterization and surgical planning in these cases.[7]

Tractography images provide more accurate details regarding infiltration of spinal cord tracts compared to conventional MR imaging and, thus, helps in prognosticating and guiding surgical management.

In cases of extramedullary intradural lesions, tractography images confirm the anatomic location, relation of lesion to spinal cord, and degree of compression of tracts and, thus, provide useful information for surgical treatment.[9] Surgical resection has the curative potential in most of the extramedullary intradural lesion due to their benign nature.[8]

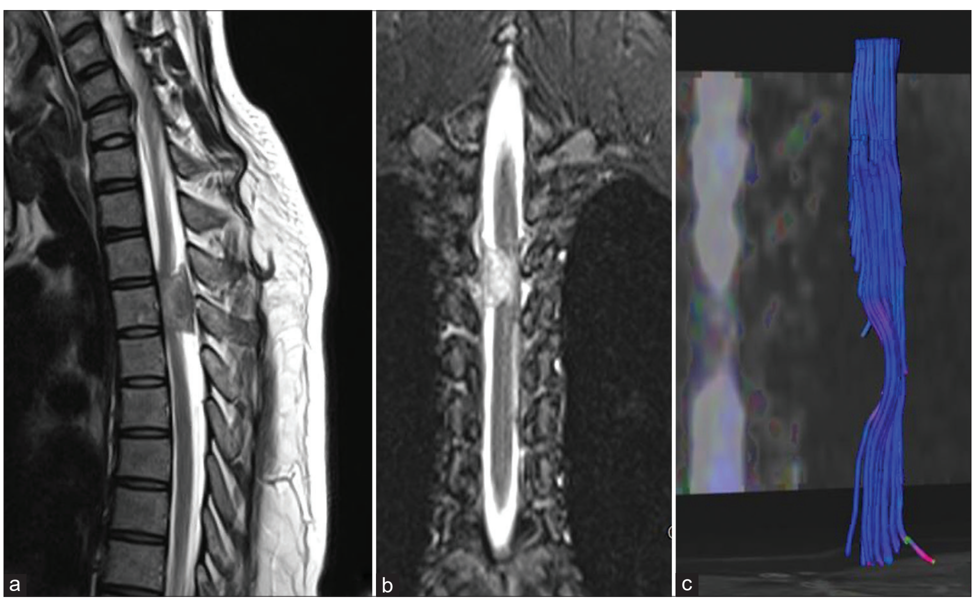

Figure 4: (a) Sagittal T2WI of cervical spine shows extramedullary intradural lesion with heterogeneous hypointense signal at D2-D4 level. (b) Homogeneous contrast enhancement is noted on coronal post-contrast T1WI FS with dural tail sign. Diagnosis – spinal meningioma. (c) Tractography image shows compression of white matter tracts at level of lesion with no evidence of infiltration of tracts.

In our cases, the diffusion tensor imaging added around 9 min to the acquisition time and a further 5 min were required for post processing of data and generation of tractography images. Based on our study findings, DTI should be considered in all cases of intradural spinal neoplasms, especially for pre-surgical planning.

CONCLUSION

Diffusion Tensor Imaging proved helpful in classification, characterization, and treatment planning of Intradural Spinal Tumors.

TEACHING POINTS

1. Tractography and DTI parameters, especially FA, are very useful in characterization of intradural spinal neoplasms and determining resectability and surgical planning.
2. Tractography can identify infiltration of spinal cord tracts in cases of intramedullary neoplasm and differentiate Astrocytomas (Infiltrative) from Ependymomas (Non-Infiltrative).

MCQs

1. Which of the following is an extramedullary intradural tumor of spine?
   a. Astrocytoma
   b. Ependymoma
   c. Hemangioblastoma
   d. Meningioma

Answer Key: d

2. FA value will be lowest in which of the following spinal tumors?
   a. Astrocytoma
   b. Schwannoma
   c. Meningioma
   d. Ependymoma

Answer Key: a

3. Which of the following statements is true about spinal astrocytoma?
   a. It is an extramedullary intradural tumor
   b. Destruction and infiltration of spinal cord tracts is noted on tractography.
   c. It is non-infiltrative and causes displacement of spinal cord tracts
   d. It shows homogeneous intense contrast enhancement.

Answer Key: b

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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