10.5005/jp-journals-10039-1055

REVIEW ARTICLE

Imaging of Spinal Cord Compression: Magnetic Resonance Imaging and Beyond

[1]Sanjitha Sivasubramanian, [2]Mathew Cherian, [3]Pankaj Mehta, [4]JKBC Parthiban

ABSTRACT

Imaging plays a crucial role in spinal cord compression. Routine magnetic resonance imaging (MRI) sequences often detect pathological changes occurring in the cord only in the late stages of the disease process. Diffusion tensor imaging (DTI) is a novel imaging technique which has the potential to identify the course of nerve fiber tracts and detect early microstructural changes occurring in the cord ahead of the other techniques. Cord changes occur in the form of altered DTI values, such as fractional anisotropy, mean diffusivity, which add functional information to the imaging report.

Keywords: Diffusion tensor imaging, Magnetic resonance imaging, Spinal cord, Spondylosis.

How to cite this article: Sivasubramanian S, Cherian M, Mehta P, Parthiban JKBC. Imaging of Spinal Cord Compression: Magnetic Resonance Imaging and Beyond. J Spinal Surg 2015;2(2):48-51.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Spinal cord compression continues to be a common clinical problem encountered in any neurological practice. Although several conditions, like tumor, abscess, trauma, malformations, etc. contribute to this clinical entity, intervertebral disk herniation by and large continues to be the singlemost common etiology of nontraumatic spastic paraparesis and quadriparesis.

In a majority of patients, the disease progresses slowly over the years, after it has been initially detected. The investigation of choice for cervical spondylotic myelopathy (CSM) is magnetic resonance imaging (MRI).[1] The limitation of routine imaging is that the signal changes in the cord occur late in the course of the disease, when the symptoms are nearly irreversible. Hence, there occurs a definite need for imaging techniques which can detect pathological changes in the cord much earlier.

[1]Resident, [2]Head, [3]Professor, [4]Senior Consultant and Head

[1]Department of Radiology, Kovai Medical Center and Hospital Coimbatore, Tamil Nadu, India

[2,3]Department of Diagnostic and Interventional Radiology, Kovai Medical Center and Hospital, Coimbatore, Tamil Nadu, India

[4]Department of Neurosurgery, Kovai Medical Center and Hospital, Coimbatore, Tamil Nadu, India

Corresponding Author: Sanjitha Sivasubramanian, Resident Department of Radiology, Kovai Medical Center and Hospital Coimbatore, Tamil Nadu, India, Phone: 4323800, e-mail: s.sanjitha@yahoo.co.in

DIFFUSION

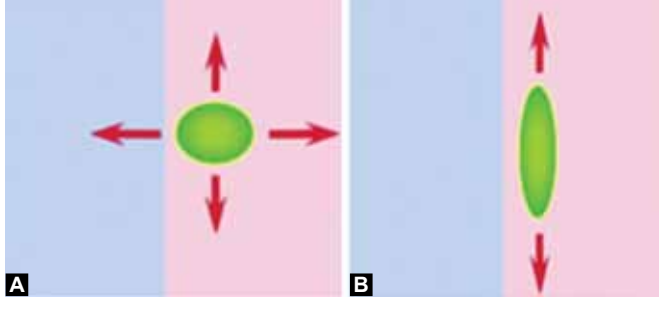
Water molecules in cells of the living body exhibit a random translational movement, called as brownian motion or diffusion by nature of their inherent latent thermal energy. It is of two types isotropic when there is unrestricted motion in all directions, anisotropic when the preferential motion is along one direction, e.g. axons, muscle fibers. This anisotropic diffusion forms the basis of diffusion tensor imaging (DTI) (Figs 1A and B).[2-4]

DIFFUSION TENSOR IMAGING

All longitudinal structures imaged are broken down into smaller three-dimensional (3D) units called voxels. Diffusion tensor imaging can track the integrity of longitudinal structures, like white matter tracts by assessing the speed and direction of diffusion in the adjacent voxels. The changes in DTI are evaluated either by 'fiber tracking techniques' (tractography) or by measuring DTI anisotropy metrics, like fractional anisotropy, mean diffusivity, transverse and longitudinal diffusivity which are mapped by specialized software provided in the MRI unit, in addition to the routinely employed MRI sequences. Tractographic techniques enable us to trace the path of nerve fiber tracts and identify the deviation or disruption in the course of the tracts (Fig. 2).[5,6]

DIFFUSION TENSOR IMAGING OF SPINAL CORD

Diffusion tensor imaging of the spinal cord has not gained much popularity as in the brain due to the poor spatial resolution, smaller cross-sectional area of the spinal cord,



Figs 1A and B: (A) Isotropic diffusion and (B) anisotropic diffusion

CSF pulsatious and magnetic susceptibility artefacts. However, current technology with the advent of special techniques enables better resolution with fewer artefacts.

TECHNIQUE

Two methods can be employed for spinal cord DTI—the routinely used sagittal DTI and axial. Several studies have shown that the region of interest (ROI) used for calculating the DTI metrics tends to include more of gray matter along with the white matter, as delineation of gray and white matter is not feasible in sagittal plane.[7] But in the axial plane of imaging the central H shaped gray matter stands out against the peripheral white matter, and the DTI metrics can be computed with values acquired only from the white matter tracts (Figs 3A and B). The commonly used indicators are fractional anisotropy and mean diffusivity.

PATHOGENESIS

The fractional anisotropy (FA) values are decreased and ADC values are increased in chronic spondylosis, compared to normal volunteers (Figs 4 and 5). This is well in accordance with the fact that prolonged compression, cell death, demyelination, and degeneration occur resulting in increased extracellular water which increases the ADC and lowers the FA values.[8] These changes are akin to the diffusion model in brain infracts. Long time of compression on the cord results in turbulent CSF flow to penetrate into the cord substance and induce intramedullary microcystic changes that cannot be imaged in routine magnetic resonance imaging (MRI) studies.[9,10] On the other hand, in acute compression like trauma, the ADC values show a decline.[11] These altered values in acute injury may mirror the cytotoxic edema with disrupted cell membrane and increased permeability along with loss of axons.[12]

Factors, like signal changes in cord in routine T2 sequence and cervical canal cross-sectional area do not predict the clinical outcome of patients. What these signal changes represent has been a matter of speculation. It could mean pathological states, like edema, gliosis, myelomalacia depending upon the time of presentation. Ischemia of the anterior spinal arteries may well be a causative factor in these hyperintensities.[13]

The information yielded from DTI can clarify the nature of the disease and the chronicity of T2 hyperintensities. Along with the clinical evaluation of patient condition, this can improve the sensitivity of imaging to predict the clinical spectrum of spondylosis.

Bony factors, like stenosis of the cervical canal, disk bulge, thickened ligaments seen in routine MRI can be suggested as reasons for clinical symptoms in a normal appearing cord, but DTI can demonstrate changes by altered parameters which directly imply cord pathology.

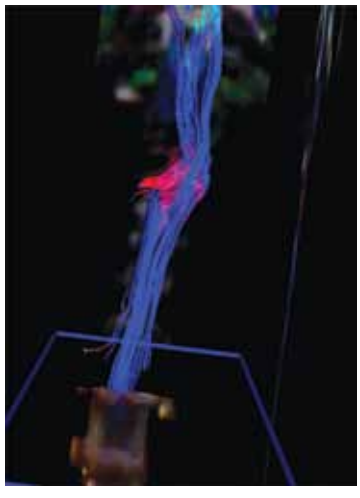
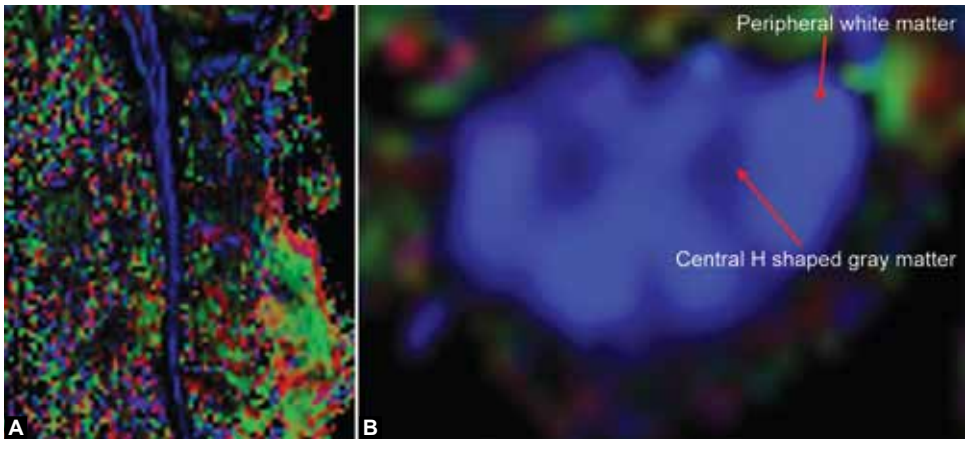


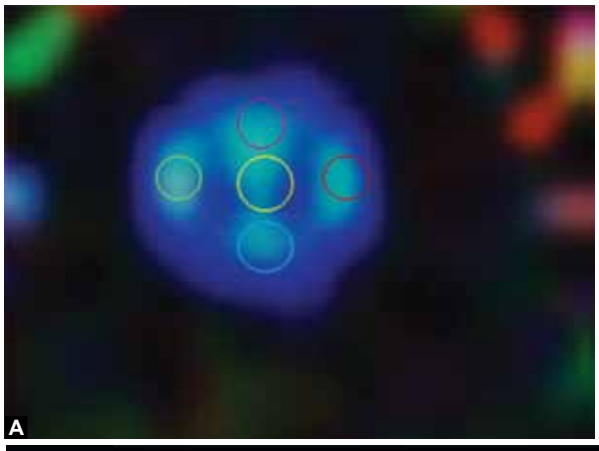
Fig. 2: Tractography of a cord showing color change (red) and deviated tracts fibers in a case of chronic cord compression

CONCLUSION

Diffusion tensor imaging can image cord compression at the microstructural level and evaluate microcystic changes, edema at a very early stage, which are not imaged by the normal MRI sequences.[5] Patients with significant symptoms of cord compression show changes in DTI and it may thus provide more functional information



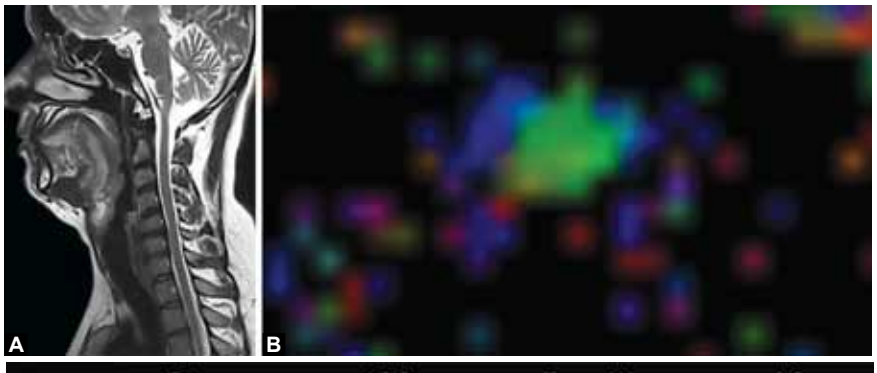
Figs 3A and B: (A) Sagittal DTI does not differentiate between gray and white matter and (B) axial DTI allows gray-white differentiation



ID	FA Mean	FA SDev	FA Size / Min / Max	ADC Mean	ADC SDev	ADC Size / Min / Max	TraceW Mean	TraceW SDev	TraceW Size / Min / Max	b0 Mean	b0 SDev	b0 Size / Min / Max
1	752.0	39.1	3 / 712 / 805	1381.0	212.0	3 / 1083 / 1558	96.3	6.5	3 / 88 / 104	386.3	63.0	3 / 306 / 460
2	753.0	82.0	3 / 695 / 869	1087.7	127.1	3 / 979 / 1266	102.7	10.8	3 / 91 / 117	305.3	41.4	3 / 252 / 353
3	703.7	89.2	3 / 580 / 787	1238.0	246.1	3 / 899 / 1476	122.7	16.8	3 / 103 / 144	422.0	48.2	3 / 354 / 460
4	748.0	163.0	2 / 585 / 911	1135.0	221.0	2 / 914 / 1356	107.5	0.5	2 / 107 / 108	342.0	76.0	2 / 266 / 418
5	905.3	79.7	3 / 805 / 1000	908.3	145.0	3 / 728 / 1083	103.0	3.7	3 / 98 / 107	258.3	42.4	3 / 203 / 306

B

Figs 4A and B: (A) Diffusion tensor imaging metrics of a normal healthy volunteer with values calculated by placing region of interest (ROI) only in white matter and (B) the fractional anisotropy (FA) and ADC-mean diffusivity values are within normal limits



ID	FA Mean	FA SDev	FA Size / Min / Max	ADC Mean	ADC SDev	ADC Size / Min / Max	TraceW Mean	TraceW SDev	TraceW Size / Min / Max	b0 Mean	b0 SDev	b0 Size / Min / Max
1	586.5	32.3	4 / 542 / 630	1606.8	138.7	4 / 1393 / 1761	112.3	4.3	4 / 105 / 116	563.5	69.1	4 / 463 / 658
2	539.5	131.5	2 / 408 / 671	1556.5	39.5	2 / 1517 / 1596	116.5	43.5	2 / 73 / 160	544.5	182.5	2 / 362 / 727
3	561.0	71.8	3 / 460 / 620	2482.7	60.9	3 / 2430 / 2568	36.0	12.0	3 / 19 / 45	438.7	162.8	3 / 213 / 591
4	551.3	69.1	3 / 476 / 643	1533.3	24.1	3 / 1512 / 1567	122.3	10.3	3 / 109 / 134	566.0	34.0	3 / 523 / 606
5	606.5	37.7	4 / 563 / 645	1514.8	91.2	4 / 1367 / 1608	114.0	4.9	4 / 109 / 122	519.5	32.9	4 / 480 / 570

C

Figs 5A to C: A 32-year-old female with C5-6 symptoms: (A) T2 MRI sequence appearing near normal, but showing color change in DTI, (B) the FA values are decreased and ADC increased at C5-C6 level and (C) compared to normal volunteers

than conventional MR imaging. Axial DTI provides more anatomical information than sagittal DTI. Hence, the routine MRI sequences can be supplemented by this novel MRI technique as a part of functional imaging in cases of cord compression to aid in early diagnosis, and hence better patient management.

REFERENCES

1. Emery SE. Cervical spondylotic myelopathy: diagnosis and treatment. J Am Acad Orthop Surg 2001;9:376-388.
2. Beaulieu C. The basis of anisotropic water diffusion in the nervous system. NMR Biomed 2002;15:435-455.
3. LeBihan D. Molecular diffusion nuclear magnetic resonance imaging. Magn Reson Q 1991;7:1-30.
4. Mukherjee P, Berman JI, Chung SW, et al. Diffusion tensor MR imaging and fiber tractography: theoretic underpinnings. Am J Neuroradiol 2008;29:633-642.
5. Facon D, Ozanne A, Fillary P, et al. MR diffusion tensor imaging and fiber tracking in spinal cord compression. Am J Neuroradiol 2005;26:1587-1594.
6. Wang W, Qin W, Hao N, Wang Y, Zong G. Diffusion tensor imaging in spinal cord compression. Acta Radiol 2012;53:921.
7. Kang M, Anderer E, Elliott R, et al. Diffusion tensor imaging of the spondylotic cervical spinal cord: a preliminary study of quantifiable markers in the evaluation for surgical decompression. The Internet J of Head and Neck Surgery 2011;5.
8. Mamata H, Jolesz FA, Maier SE. Apparent diffusion coefficient and fractional anisotropy in spinal cord: age and cervical spondylosis-related changes. J Magn Reson Imaging 2005; 22(1):38-43.
9. Levine DN. Pathogenesis of cervical spondylotic myelopathy. J Neurol Neurosurg Psychiatry 1997;62:334-340.
10. Hansen B, Flint JJ, Heon-Lee C, et al. Diffusion tensor microscopy in human nervous tissue with quantitative correlation based on direct histological comparison. Neuroimage 2011;57(4):1458-1465.
11. Shanmuganathan K, Gullapalli RP, Zhuo J, Mirvis SE. Diffusion tensor MR imaging in cervical spine trauma. Am J Neuroradiol 2008;29:655-659.
12. Kamble RB, Venkataramana NK, Naik AL, Rao SV. Diffusion tensor imaging in spinal cord injury. Ind J Radiol Imaging 2011;21:221-224.
13. Mifsud V, Pullicino P. Spinal cord MRI hyperintensities in cervical spondylosis: an ischemic pathogenesis? J Neuroimaging 2000 Apr;10(2):96-100.