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ORIGINAL ARTICLE

Diffusion tensor imaging of periventricular leukomalacia – Initial experience

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Eman M. Abdelsalam [a,*], Mohamed Gomaa [b], Lamiaa Elsorougy [a]

[a] *Radiodiagnosis Dpt., Faculty of Medicine, Mansura University, Egypt*
[b] *Neurology Dpt., Faculty of Medicine, Mansura University, Egypt*

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KEYWORDS

DTI: diffusion-tensor imaging;
DTT: diffusion tensor tractography (DTT);
PVL: periventricular leukomalacia;
CP: cerebral palsy

Abstract *Aim of the study:* To investigate the role of MR diffusion tensor imaging (DTI) and diffusion tensor tractography (DTT) in the assessment of altered major white matter fibers in preterm infants and children with PVL.

Patients and methods: We used diffusion tensor imaging to evaluate the major white matter tract fibers in 15 children with periventricular leukomalacia in correlation with cognitive and motor disability. Mean age of the patients was 28.5 months (range: 9–84 months). 5 normal control children were recruited (mean age: 21.4, range: 11–60 months). MR imaging was obtained by using a 1.5-T, whole-body scanner. DTI was acquired after the routine sequences. Then, data post-processing and fiber-tracking method was applied.

Results: This study demonstrated the existence of the WM tract injury in PVL patients using the DTI tractography approach in correlation with neurodevelopmental delay in patients with various degrees of cognitive and motor impairment. Compared with the normal control group, the following abnormalities were detected on qualitative analysis of the white matter tracts.

Corticospinal tracts: Decreased volume and cross-sectional area on the affected side.

Ascending sensorimotor tracts: Thinning of sensory fiber tracts and posterior thalamic radiations.

Commissural and association tracts: Significant damage of the callosal fibers was reported in cases with partial agenesis of the corpus callosum.

Conclusion: DTI proved to be a promising noninvasive method for assessing the severity of white matter tract injury in patients with PVL. This is owing to the capability of fiber-tracking techniques to provide more information for understanding the pathophysiologic features of sensorimotor and

Abbreviations: DTI, diffusion-tensor imaging; DTT, diffusion tensor tractography (DTT); PVL, periventricular leukomalacia; CP, cerebral palsy; WM, white matter; FA, fractional anisotropy; CST, corticospinal tract; SF, sensory fiber tracts; PTR, posterior thalamic radiations; CC, corpus callosum.

* Corresponding author.

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cognitive disability associated with PVL. This will allow for the early intervention and initiation of rehabilitation programs aiming for minimizing the associated neurological deficit.

1. Introduction

Diffusion-tensor imaging (DTI) is a powerful MR imaging method to probe tissue microstructure by using the diffusion of water molecules. Diffusion tensor tractography (DTT) is a unique method to reconstruct and visualize the three-dimensional tracts noninvasively, which has not been possible before with any other imaging modality (1).

By applying the appropriate magnetic field gradients, MR imaging may be sensitized to the random, thermally driven motion (diffusion) of water molecules in the direction of the field gradient. Diffusion is anisotropic (directionally dependent) in white matter fiber tracts, as axonal membranes and myelin sheaths present barriers to the motion of water molecules in directions not parallel to their own orientation. The direction of maximum diffusivity has been shown to coincide with the WM fiber tract orientation (2).

This information is contained in the diffusion tensor, a mathematic model of diffusion in three-dimensional space. In general, a tensor is a rather abstract mathematic entity having specific properties that enable complex physical phenomena to be quantified (3). In the present context, the tensor is simply a matrix of numbers derived from diffusion measurements in several different directions, from which one can estimate the diffusivity in any arbitrary direction or determine the direction of maximum diffusivity. The tensor matrix may be easily visualized as an ellipsoid whose diameter in any direction estimates the diffusivity in that direction and whose major principle axis is oriented in the direction of maximum diffusivity (4) (Fig. 1).

The shape of the resulting diffusion ellipsoid is described by the resulting primary eigenvectors and eigenvalues. From these indices, quantitative measures of diffusion anisotropy, such as the fractional anisotropy, can be calculated (5). This summary measure, along with other quantitative diffusion indices such as the directionally averaged mean diffusivity (also referred to as average apparent diffusion coefficient, abbreviated as MD, Dav or ADCave) have proved useful for probing the integrity and development of white matter pathways in the brain (6).

It is well known from studies of animals (7) and adult humans (8) that DTI can serve as an early indicator of stroke, often demonstrating image abnormalities on water diffusion maps well before conventional MRI. Early detection of injury is particularly critical in the context of administration of neuroprotective therapies to infants. These therapies must be initiated quickly in order to interrupt the cascade of irreversible brain injury (9). Water diffusion maps derived from DTI may provide the means for this early detection of injury. Changes in diffusion characteristics further provide early evidence of both focal and diffuse brain injury in association with

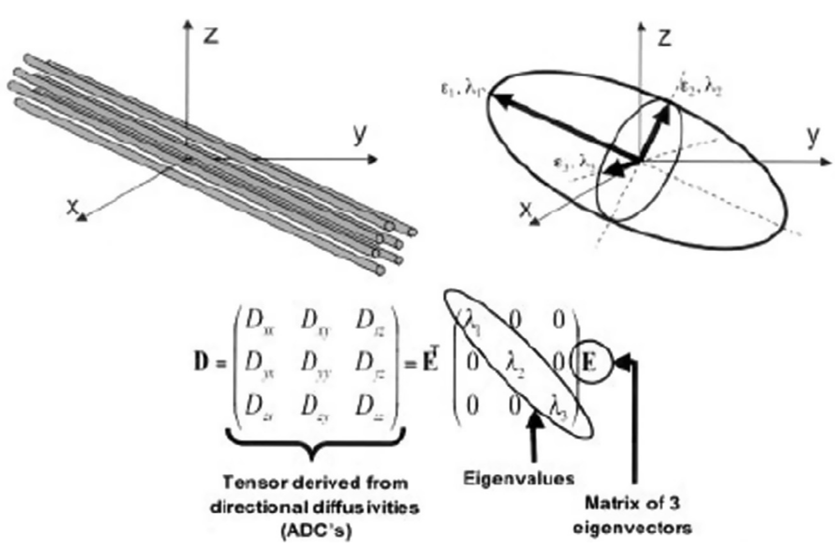

Fig. 1 Top left, Fiber tracts have an arbitrary orientation with respect to scanner geometry (*x*, *y*, *z* axes) and impose directional dependence (anisotropy) on diffusion measurements. Top right, The three-dimensional diffusivity is modeled as an ellipsoid whose orientation is characterized by three eigenvectors (€2, €2, €3) and whose shape is characterized by three eigenvalues (λ1, λ2, λ3). The eigenvectors represent the major, medium, and minor principle axes of the ellipsoid, and the eigenvalues represent the diffusivities in these three directions, respectively. Bottom, This ellipsoid model is fitted to a set of at least six noncollinear diffusion measurements by solving a set of matrix equations involving the diffusivities (ADCs) and requiring a procedure known as matrix diagonalization. The major eigenvector (that eigenvector associated with the largest of the three eigenvalues) reflects the direction of maximum diffusivity, which, in turn, reflects the orientation of fiber tracts. Superscript T indicates the matrix transpose. Quoted from: Brian et al. (4).