Diffusion tensor imaging detects the spatial variation in fiber angle and lamellar number in intact human discs

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Purpose

The biological and physiological modifications of the disk tissue's structure underlie the loss of its functional integrity and ultimately, loss of its performance as a mechanical joint. This study investigated the use of tensor diffusion imaging to directly interrogate the spatial orientation of collagen fibers' in intact human disks.

Methods

Four human lumbar cadaver spinal disc units (L2-L3), from donors age 48 and 52 years, were scanned using a 9.4 Tesla scanner (Bruker Biospin MRI GmbH, Ettlingen, Germany) equipped with an actively shielded 400 mT/m gradient coil (Bruker, BGA12S). The disks were imaged in 72 mm inner-diameter quadrature birdcage coil with the disk's caudal-cranial axis aligned with the main static magnetic field direction (laboratory z-axis).

Diffusion Tensor Imaging: 3D spin-echo echo-planar imaging (SE-EPI) diffusion tensor image data was acquired using 30 non-collinear directions and 2 averaged b_0 images with: b = 670 s/mm^2, TE/TR = 29/700ms, NEX = 8, FOV= (56 x 50 x 16)mm, acquisition matrix= 290 x176 x 16, reconstructed resolution= (193 x 195 x 500)µm. Imaging time=10 hours. DTI data was reconstructed in Slicer 3D (v.4.1, www.slicer.org) and a weighted least-squares algorithm used to estimate the 3D diffusion tensor from the diffusion weighted images. DTI data set was analyzed directly from the 3x3 diffusion tensor (V.14, Matlab, Mathworks) and the orientation angle relative to the axial plane of the disk computed at each voxel.

Results

The DTI analysis showed clear demarcation of the AF and NP regions (Fig 1.[A]) with fine details of the annuls structure demonstrated by the number of laminae. In agreement with histological studies [1], analysis of fiber angles at the anterior, lateral and posterior regions [B] shows the increase in fiber angle as a function of region within the AF. Of note is the increase in the fibers angle dispersion at the posterior region.

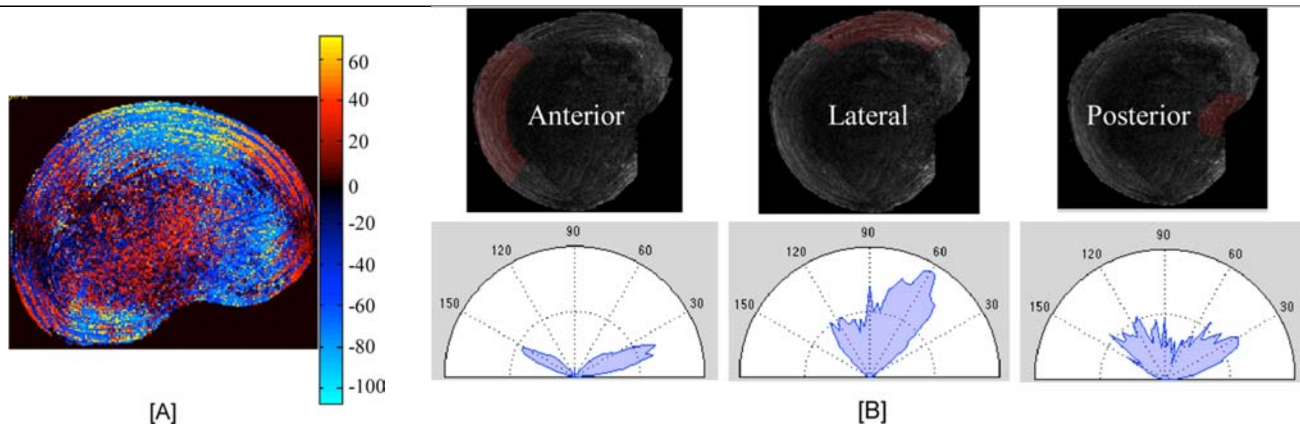

Fig. 1. Fiber angle based segmentation of the DTI data set shows discrete, alternating, lamella structure in the AF and a near uniform structure in the NP [A].

Discussion

In close agreement with histological studies [1], fiber angle within the AF increased from the anterior to the posterior aspect of the disk with respect to its transverse plane. We are able to count the number of lamellae as a function of location around the circumference of the disk. Since disk degeneration produces, among other things, a loss in the number of laminae, this permits a more detailed assessment of the structural effects of disk degradation. This approach also permits evaluating the range of fiber orientations as a function of degeneration. This protocol will enable us to provide novel data on the effects of degenerative changes in the disc, on the relationships between structure and composition and, in turn, their effect on the mechanical behavior of the disk.

Conclusion

This study, **for the first time**, showed the ability to directly visualize fiber angle and the number of lamina in the AF within **the intact disk**.

References

1. Marchand, F. and A.M. Ahmad, *Investigation of the laminate structure of lumbar disc annulus fibrosus.* Spine, 1990. 15(5): p. 402-408.