Visualization of Laminar and Columnar Organization in Rat Olfactory Bulb using Diffusion Tensor MRI

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Introduction:

Diffusion Tensor Imaging [1] (DTI) has extensively been used for imaging white matter tracks in the brain. However, use of DTI in imaging laminar and columnar organization has not been explored in depth to our knowledge. The well-characterized laminar structure in the rat Olfactory Bulb (OB) [5] and the presence of radially oriented columns [2] make it an excellent candidate for testing the sensitivity of DTI to cortical organization. The results presented in this abstract suggest that the laminar and columnar organization can be visualized using DTI in the rat OB. Three different layers with high anisotropy, showing directionality consistent with previously known anatomical structure of OB, are visualized. Radially oriented columnar structure is also observed.

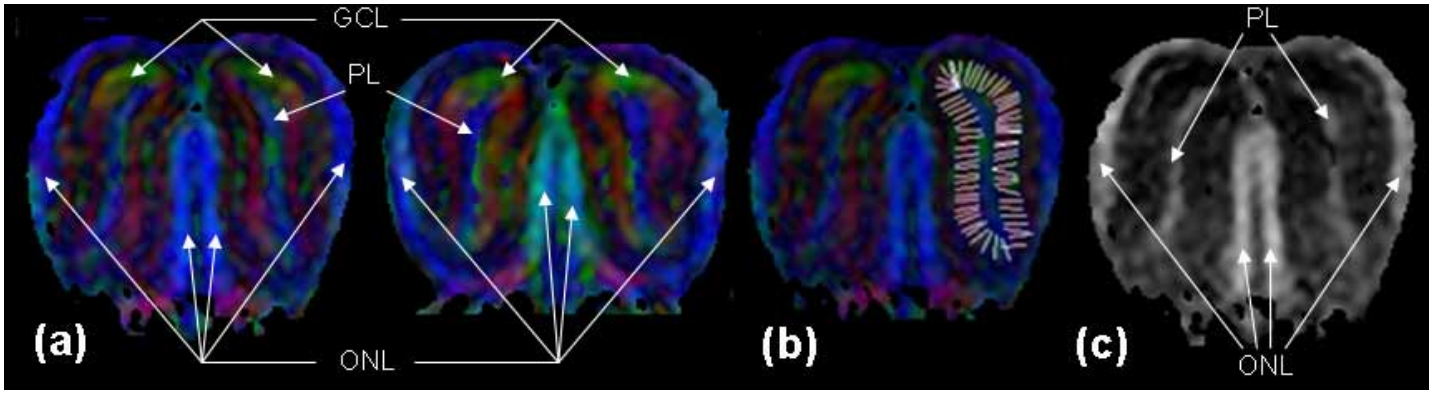
Material and Methods:

Adult Sprague Dawley rats (n = 2) were euthanized prior to imaging. All imaging experiments were performed on Bruker 9.4T. Coronal images of olfactory bulb were acquired using a spin echo DTI sequence with following parameters: TR = 1.5 s, TE = 18 ms, FOV = 2.2 × 2.2 cm^2, matrix size = 128 × 128 (512 × 512 after zero-filling), slice thickness = 0.5-1 mm, NEX = 2. Six gradient directions following an optimized scheme presented in [3] were used with 4 b-values (600, 800, 1200, 1550) per direction. Four images with b = 0 were acquired and the total imaging time was 3 hours. Diffusion tensors were estimated using linear least square fitting. The principal directions were calculated and RGB images were created with red, green and blue representing horizontal, vertical and through-plane orientations respectively. The images were modulated with fractional anisotropy (FA). Directionality at different user-selected points in the plane of section was displayed.

Results and Discussion:

Three layers showing high anisotropy were identified in all the color maps as shown in Fig *a*: 1) Olfactory Nerve Layer (ONL), 2) Granule Cell Layer (GCL), 3) a layer showing high through-plane orientation in the inner part of the bulb. This layer is referred to as PL (projection layer) henceforth for brevity.

As apparent in figures *a* and *c*, ONL shows high level of through-plane (blue) component. This is expected because the axons in ONL run in rostral to caudal direction to convey information from sensory neurons to the glomeruli [4]. It is interesting to note that high anisotropy is observed in ONL despite the fact that ONL axons are unmyelinated [5]. GCL appears to have highly organized radial columnar organization, based upon the contours showing orientation of manually selected points in GCL (Fig. *b*). This observation is consistent with the results presented in a viral tract tracing study, showing the presence of radially directed columns in the OB [2]. High through-plane directionality is observed in PL (Fig. *c*), which is what we expected because mitral cell axons in this region run in rostral to caudal direction in order to convey information from OB to more caudal part of the brain.



a) Color maps obtained from two different rats. High anisotropy in GCL is due to fibers running in radial direction, as shown in Fig. *b* **b)** Contours showing principal direction of manually selected points in GCL **c)** Through-plane (blue) component of the FA-modulated RGB image.

These results suggest the possibility of using DTI for visualization of fine laminar and columnar structure in brain. We plan to continue this work by acquiring DTI images of OB in coronal and sagittal planes. We also intend to test the sensitivity of DTI to other cortical structures, such as whisker barrels in rodents. These preliminary results suggest that DTI will prove a useful tool for studying changes in fine details of cortical structure following disease or during development.

References:

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