Novel Olfactory System Neural Organization Revealed by Diffusion Tensor MRI

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Introduction

Histological evidence suggests that the elasmobranch fishes demonstrate a remarkably different olfactory bulb organization than higher level vertebrates, including the teleost fishes (Dryer and Graziadei, 1993; Meredith et al., *in press*). We show that Diffusion Tensor Imaging (DTI) can be applied to map complex neural pathways in the elasmobranch olfactory system, and reveal that elasmobranchs possess a unique somatotopic organization of fiber tracts within the olfactory bulb, confirming results obtained from histology [2,3]. This contrasts with teleost fishes which possess a chemotopic organization whereby olfactory receptor neurons that share similar chemical sensitivity converge in glomeruli regardless of their point of origin within the olfactory epithelium [4,5].

Experimental

The olfactory tissue of an Atlantic stingray (*Dasyatis sabina*) was imaged at the University of Florida National High Magnet Field Laboratory facility using a 17.6 T Bruker MRI scanner. DTI was performed using a standard multislice pulsed gradient spin echo pulse sequence with an in-plane resolution of 39 μm x 39 μm and a slice thickness of 150 μm and 12 gradient directions at a b-value of 1000 s/mm^2. Imaging parameters were TR = 3500 ms, TE = 20.3 ms, 16 averages for a total acquisition scan time of ~26 hrs. Data were denoised using the non-local means technique before the diffusion tensor was estimated [6]. The diffusion tensor estimation and fiber tracking were performed using fanDTasia™ [7].

Results and Discussion

DT-MRI and FTM revealed clear fiber tracts that appear to extend from the olfactory receptor neurons in the epithelium of the secondary lamellae (green, horizontal lines), along the lamina propria of the primary lamellae (red, vertical lines), and then directly posterior to the olfactory bulb (Figure 1b). Of particular interest is the observation that the fiber tracts project from the primary lamellae to glomeruli in the olfactory bulb with minimal lateral divergence within the bulb. Because the axons project laterally only a short distance (1-2 lamella widths) they maintain a spatial organization along the length of the bulb that corresponds to their location along the length of the rosette. This spatial correspondence has the potential to provide an olfactory somatotopic map, which may be a feature unique to the elasmobranchs and is supported by histological evidence [2,3].

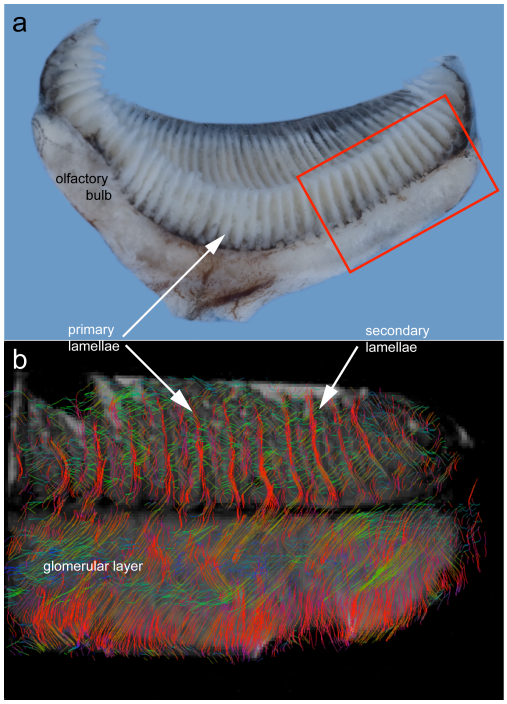

Figure 1. (a) Olfactory organ with imaged section in red box. (b) DTI tractography revealing somototopic neuronal organization.

Conclusions

This study demonstrates the ability of very high resolution DTI to elucidate the novel finding of a unique neural connectivity in the elasmobranch olfactory system. Unlike in human neuroanatomy, little is known about the neural structure of most species and an understanding of neural connectivity is crucial to understanding how vertebrates have evolved. DTI can generate accurate representations of highly complex neural structures that would be prohibitive or impossible using traditional histological techniques, revealing evolutionary novelties in neural organization that greatly enhance our understanding of comparative neuroanatomy.

Acknowledgements

Funding for this project came from a Florida Atlantic University Division of Research Seed Grant (SMK), NSF-EF-0850369 (LRF), NSF DBI-1147260 (LRF) and R01 MH096100 (LRF).

References

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