

Detailed laminar characteristics of the neocortex revealed by NODDI

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Diffusion weighted imaging (DWI) can provide a rich description of cortical architecture, *in vivo*¹ as well as *ex vivo*². Diffusion properties of the primary visual cortex (V1) have been shown to be layer-specific³. Here, we extend these findings by fitting the NODDI tissue model⁴ to multi-shell DWI data to support an improved division of cortical layers.

Samples of human V1 were fixed in formalin (>2 months), soaked in phosphate buffered saline (>72h) and scanned in a proton-free fluid. Diffusion data were acquired for eight shells ($b=0-20000 \text{ smm}^{-2}$) sampled in 384 directions with 200 μm isotropic spatial resolution on a 9.4T preclinical MR system equipped with a cryogenic probe. Four tissue compartments (1. neurite volume fraction (axons+dendrites/cylindrical structures); 2. space around the cylinders; 3. a CSF compartment; 4. an isotropic restricted compartment⁵) and the fibre orientation dispersion (kappa, concentration around the dominant direction) were fitted using the NODDI toolbox.

On the basis of the neurite volume fraction (ficvf) the cortex could be divided in three layers: the superficial layers, the stria of Gennari and the deep layers. Neurite density was higher in deep vs. superficial layers, but highest for the stria of Gennari. The contrast between the layers was larger for neurite density (ficvf) as compared to the mean kurtosis (left graph). The orientation dispersion resolves additional layers. From pial to the WM surface, the superficial layers show a gradient of increasing dispersion (decreasing kappa) towards the stria of Gennari. In the cortex below the stria of Gennari can be subdivided in three layers showing with high-low-high coherence. Putatively, the low coherence layer represent the inner band of Baillarger. These patterns were reproduced in a sample of a second specimen.

The layer-specificity of diffusion in the cortex can be resolved better in NODDI parameter maps as compared to standard alternatives.

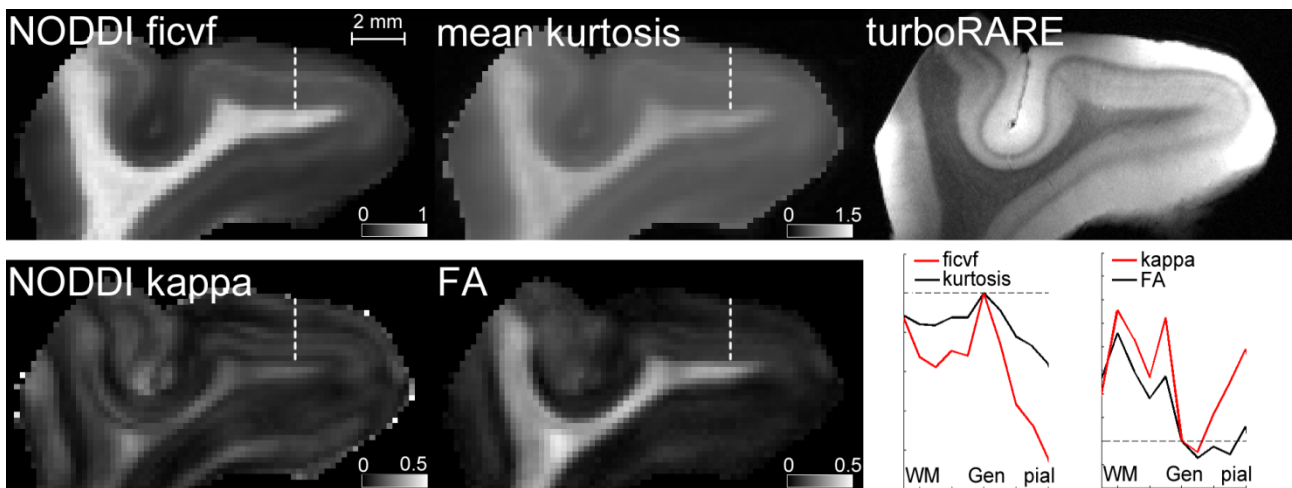


Figure 1. NODDI parameter maps (ficvf=neurite volume fraction; kappa=Watson concentration) and reference images (fa=fractional anisotropy). Graphs show cortical profiles along the dashed lines on the left, normalized to the value in the stria of Gennari (WM=gray-white matter boundary; Gen=stria of Gennari).

References:

1. Heidemann et al, NeuroImage 60 (2012), 967-978
2. Miller et al., NeuroImage 59 (2012), 2284-2297
3. Kleinnijenhuis et al., Cortex (2012), doi: 10.1016/j.cortex.2012.11.015
4. Zhang et al., NeuroImage 60 (2012), 1000-1016
5. Alexander et al., NeuroImage 52 (2010), 1374-1389