

Visualization of the Orientational Structure of the Human Stria of Gennari with High-Resolution DWI

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Introduction: The Stria of Gennari (SoG) is a highly visible layer of myelinated axons which defines the primary visual cortex V1. It can be seen with the naked eye in cadaver brain sections, and has been studied extensively in histological examination [1,2]. However, 3D structures are difficult to observe in thin layers of histological slices. The SoG is also relatively easy to observe in vivo with high field MRI, because it has different T1, T2* and phase from neighbouring tissue [3,4,5,6]. While MRI with isotropic resolution enables 3D visualization of the SoG, its orientational structure is not yet well understood. DWI at MR field strengths below 7T has insufficient sensitivity and spatial resolution to detect intracortical anisotropy. In this cadaver brain study we show for the first time that the SoG can be distinguished from surrounding cortical tissue by its orientational structure, and that V1 and the adjacent area V2 can also be discriminated by DWI measurements.

Methods: All experiments were performed on a 9.4T micro-imaging system (Bruker Avance 400, Micro 2.5 gradient system, Bruker, Germany) using a 25 mm inner diameter birdcage coil (Bruker, Germany). Scans were performed on an excised block of formalin-fixed human cadaver brain (1.5x1.5x1cm) containing part of the visual cortex (post mortem time = 24 hrs). A standard pulsed-gradient spin-echo (PGSE) sequence (TE=19.6 ms, TR=3000 ms, b=1159 s/mm², Δ =7.2 ms, 60 directions + 2 b=0, spatial resolution 188 x 188 x 376 μ m, 8 adjacent slices, 4 averages) was run, and the analysis was performed with in-house software.

Results: Fig.1 shows a section through the cadaver brain block. Within the primary visual cortex (V1) orientational anisotropy was observed in the gray matter, most prominently in the region of layer I (Fig.2, a) where the orientation was predominantly parallel to the cortical surface, and in layers II and III (Fig.2, b) where the principal eigenvectors were generally perpendicular to the cortex surface. Within the SoG, defined by its smaller T1 [6], the uniform directionality of the principal eigenvector is drastically reduced (Fig.2, c). In layers V and VI the orientation is mainly perpendicular to the cortical surface, with a few principal eigenvectors, especially in layer VI, also lying parallel to the cortical surface (Fig.2, d). In the adjacent visual area V2, the cortical microstructure is not interrupted by a Stria of Gennari, and the principal eigenvector orientation remains perpendicular to the cortical surface across almost the entire cortex (Fig.3).

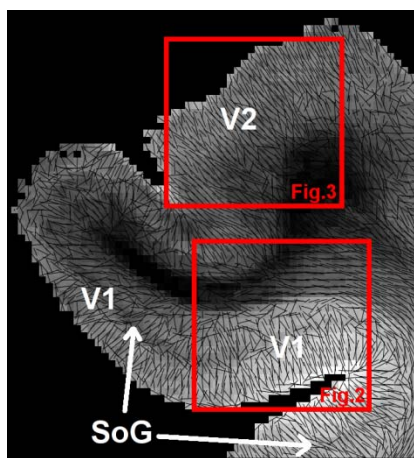


Fig.1: A single slice through the V1 block. T1 weighted image with superimposed principal eigenvectors.

Within the SoG no clearly preferred direction of the principal eigenvector can be observed, while the surrounding layers show an orientation mainly perpendicular to the cortical surface.

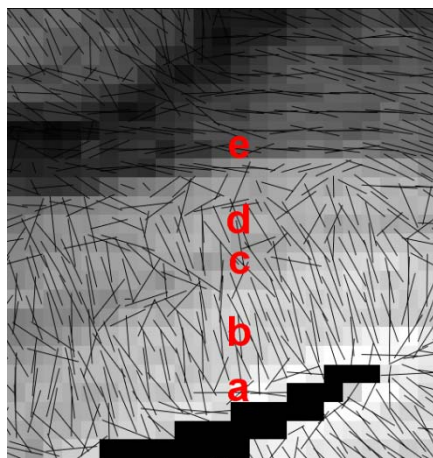


Fig.2: In V1 the DTI measurement shows 4 differentiable layers.

a - Mainly parallel to the surface
b - Mainly perpendicular to the surface
c - No preferred direction
d - Perpendicular to the surface with a few principal eigenvectors parallel to the surface
e - White matter, mainly parallel to the cortical surface

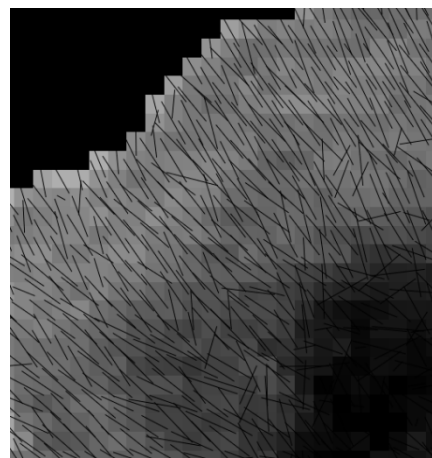


Fig.3: In V2 the principal eigenvector orientation is perpendicular to the cortical surface across almost the entire cortex. The interruption by the SoG can not be observed.

Discussion: In this study the orientational structure of the human Stria of Gennari has been visualized for the first time by high-resolution DWI measurements. Tissue orientation within the SoG was strikingly reduced. This is consistent with the known SoG myeloarchitecture, which consists of heavily-myelinated intracortical axonal fibres running parallel to the cortical surface, orthogonally crossing the dense radial bundles of myelinated axons emerging from the white matter. This fibre crossing structure can lead to reduced anisotropy. However, our observation also implies that the axons lying within the SoG have no preferred orientation in this plane. In V1, the orientational structure allows discrimination of at least four cortical layers, and enables clear differentiation between cortical areas V1 and V2. This data should enable estimation of intracortical connectivity.

References: [1] S Clarke et al. J. Comp. Neurol. 298:188-214 (1990) [2] J.Boyd et al. Cereb. Cortex 10 :644-662 (2000), [3] R. Trampel et al. Proc ISMRM 19:5 (2010), [4] V.Clark et al. Cereb. Cortex 2 :417-427 (1992) [5] H.Bridge et al. J.Vis. 5 : 93-102 (2005) [6] R.Turner et al. MRM 26 : 935-942 (2008)