Improved tract resolvability with high-resolution diffusion-weighted steady state free precession data of post-mortem human brain at 7T

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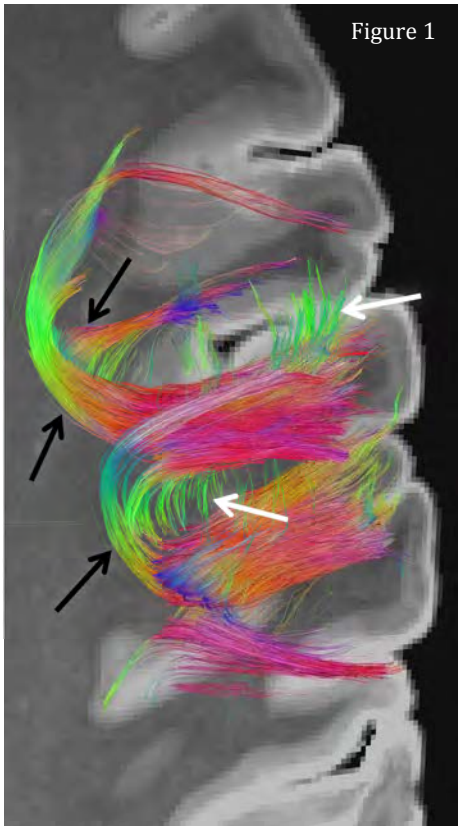
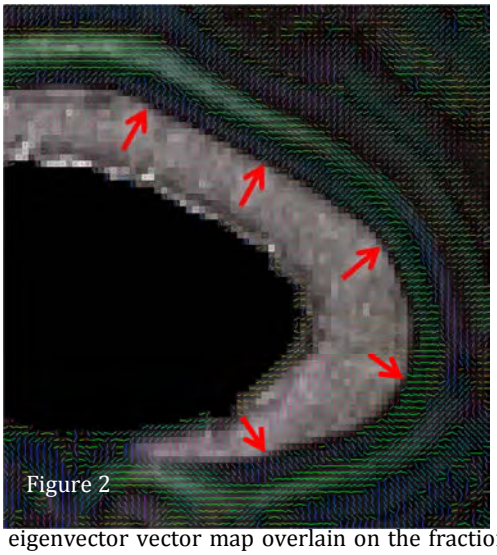
Introduction: Post-mortem human brain imaging is of growing interest for in-vivo validation studies. Use of diffusion weighted steady-state free precession (DW-SSFP)[1] has been demonstrated to perform significantly better than diffusion-weighted spin echo techniques[2] for post-mortem human brain tractography at both 3T[2] and 7T.[3] With sufficiently long scan times, whole-brain diffusion data can be acquired at very high spatial resolution, enabling investigation of anatomy that cannot easily be studied in vivo. In this work DTI data were acquired at 0.5mm isotropic resolution of a post-mortem human brain. Here we report on small tracts and other features that would be unresolved at convention resolutions.

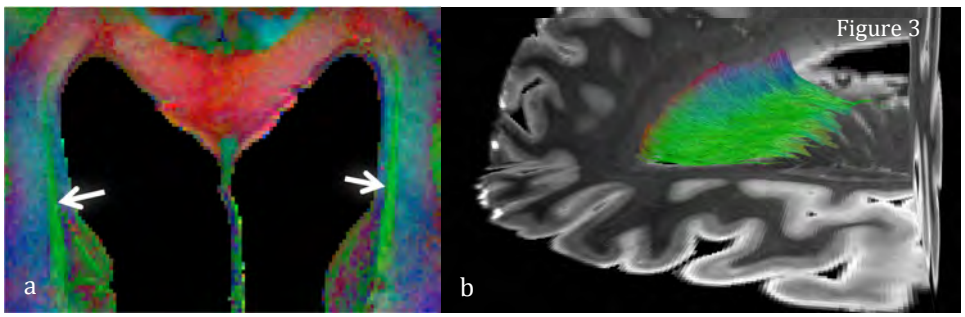
Methods: A post-mortem human brain with no known neuropathology was imaged using a Siemens 7T whole body scanner and a 32 channel receive head coil. The post-mortem interval was less than 72 hours; the scan interval, 6 weeks. The brain was packed in fluorinert for susceptibility matching. DTI data were acquired using DW-SSFP with 0.5mm isotropic resolution, over 90 directions. Post-mortem tissue has significantly reduced diffusion coefficients, requiring strong diffusion weighting. DW-SSFP scans targeted q=300 cm^{-1} to achieve the effective contrast of b_{eff}=5150 s/mm^2 (DW-SSFP has a well defined q-value, but not b-value, and b_{eff} is quoted as a reference for contrast in our data). This protocol was repeated at two nominal flip angles (33˚ and 98˚, respectively) to overcome B1 inhomogeneities at 7T. Scan duration was approximately 10 days. Principle diffusion directions (PDD) and other tensor estimates were produced using a modified version of DTIFIT that includes the DW-SSFP signal model. Deterministic tractography was performed with Trackvis.





Results: All figures demonstrate very small tracts that had been previously invisible to our previous 1mm post-mortem protocols and are typically considered difficult to track. Figure 1 shows tractography of both U-fibres (black arrows) and fibre projections in to the banks and crown of a gyrus (white arrow). Figure 2 shows a thin layer of cortex (red arrows) between the corpus callosum and the cingulum, displayed as a principle eigenvector vector map overlain on the fractional anisotropy map. Diffusion direction in this gray matter region is orthogonal to the two white matter tracts that surround it, comparable to the architecture of the grey/white matter interface in gyri[1]. Figure 3 depicts the Muratoff bundle in both (a) an RGB color map of the PDD (white arrows) as well as (b) with tractography. The RGB map reveals a very narrow laminar structure only 1-2 voxels wide. Tractography results seeded from this region reveal a thin sheet of fibres running anterior-posterior from the pons toward frontal cortex; however, tractography streamlines are pulled in to the corpus callosum; this is a consequence of using deterministic tractography with a single fibre orientation. Based on previous results, we expect that the data quality is sufficiently good to produce a secondary fibre population that may enable tracking across the corpus callosum into the frontal lobe.

Discussion: The work reports the quality of data that can be acquired in post-mortem brain using DW-SSFP at very high spatial resolution and with modestly high angular resolution. It is clear from results that tract identification is improved with resolution, albeit at a cost of extraordinarily long scan times. These methods may therefore be used to acquire exquisite detail on a limited number of brains, making these datasets highly valuable if made publicly available (as is our ultimate intention).



References:
[1]Miller, NeuroImage, 2011; [2]Miller, NeuroImage, 2012; [3]Foxley, NeuroImage, 2014