DTI BASED TRACTOGRAPHY OF FETAL ASSOCIATION FIBER TRACTS IN UTERO

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Introduction:
Association fiber tracts connect different cortical areas in the same hemisphere and therefore constitute an important anatomical substrate for a diverse range of higher cognitive functions. Association fibers have been extensively investigated in adult (Wakana et al. 2004) and pediatric subjects (Dubois et al. 2006) as well as in post mortem samples of fetal brains (Huang et al. 2009) but so far their development and 3-dimensional morphology has not been successfully visualized and characterized in the living human fetus. We used DTI based tractography to visualize major association fiber pathways in living unsedated fetuses in utero. Our aim was to compare the 3-dimensional morphology and developmental changes of different cortico-cortical association fiber tracts in fetuses of different gestational ages.

Methods:
Orthogonal axial diffusion tensor sequences (16 diffusion encoding directions, reconstructed voxel size 0.94x0.94x3mm^3, b values of 0s/mm^2 and 700s/mm^2) of 8 normal fetuses between gestational week (GW) 20 and 34 were performed using a 1.5 Tesla superconducting MR unit. Color coded FA maps were geometrically coregistered with multiplanar T2-weighted MR sequences. Main cortico-cortical association tracts were anatomically defined using a multiple ROI approach and calculated using a FACT algorithm (Philips Extended MR WorkSpace 2.6.3.2).

Results:
A fiber tract connecting the anterior temporal lobe with the frontal lobe could be consistently visualized in all 8 subjects and was identified as the uncinate fasciculus (Figure, blue trajectory). Superior to the uncinate fasciculus another fiber tract originating in the frontal lobe was found that continued posterior within the temporal lobe and sagittal stratum, and was identified as the inferior fronto-occipital fasciculus (Figure, green trajectory). In addition in three cases (3/8) fibers connecting the occipital lobe with the anterior temporal lobe inferior and lateral to the inferior fronto-occipital fasciculus were identified as the inferior longitudinal fasciculus (Figure, red trajectory). At 20 GW the examined association tracts were readily detected. Cross sectional comparison between different gestational ages showed an increase in the complexity, as well as developmental changes in the 3D morphology of developing association fiber tracts.

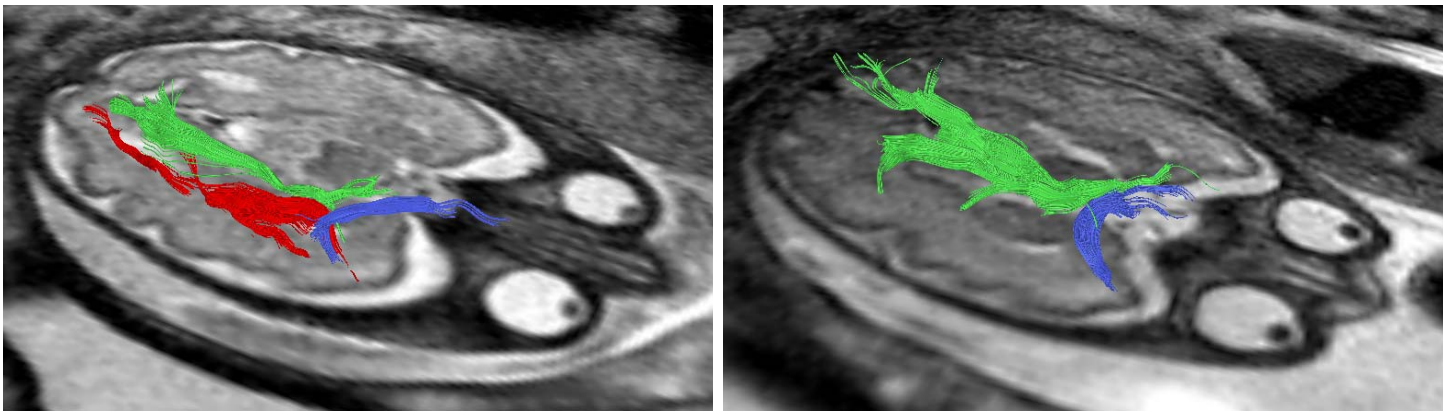

Figure: 3-dimensional visualization of developing fetal association fiber tracts in two fetuses aged 33 (left) and 34 (right) gestational weeks. Tractography shows the course and morphology of the uncinate fasciculus (blue), inferior fronto-occipital fasciculus (green) and inferior longitudinal fasciculus (red). Tractography results are displayed on a coregistered T2-weighted image.

Conclusion:
This in vivo neuroimaging study initially demonstrates the potential of DTI based tractography to visualize major association fiber tracts previously described in the adult and postmortem neuroimaging literature in living unsedated fetuses in utero as early as 20 GW. Even in fiber tracts with a prolonged development and postnatal myelination, premyelination processes lead to a sufficiently anisotropic environment to allow their reconstruction by tractography. In addition to the demonstration of the corpus callosum and sensorimotor tracts in utero, the ability of assessing association fibers and their diffusion characteristics may provide important insights into the neurodevelopmental sequelae of intrauterine white matter damage on postnatal cognitive and behavioral outcomes.

References:
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