Feasibility of connectivity-based classification of the preterm corpus callosum at term equivalent age

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Introduction: The corpus callosum (CC) is a major white matter fibre bundle, enabling the efficient interhemispheric transfer of information in the brain. In infants born preterm, development of the CC is often compromised, which can impact on motor and cognitive function later in life. Morphology of the CC can be analyzed using structural imaging, while its microstructure can be assessed with diffusion imaging [1]. Manual delineation of ROIs on the midsagittal plane if often used for analysis. However, this technique is operator-dependent and restricted to analysis of the plane(s) on which the ROIs are drawn. We investigate the feasibility of using diffusion tractography to automatically segment the CC based on its cortical connections in a cohort of very preterm infants scanned at term equivalent age.

Methods: Nine very preterm infants (5 male, mean gestational age at birth: 31^{+6} weeks) were scanned at term equivalent age (42^{+6} weeks postmenstrual age) using a 3T scanner. Infants were scanned unsedated during natural sleep, using an MR compatible incubator with dedicated neonatal head coil. The imaging protocol included a diffusion imaging sequence (b = 1000 s/mm^2, 30 directions, resolution 1.75x1.75 mm, 2 mm slice thickness). Data from one infant were excluded due to extensive head motion artefacts. Data pre-processing included correction for head movement, susceptibility distortion correction, intensity inhomogeneity correction and rejection of outlier voxels caused by motion. FA maps were generated and non-linearly registered to the JHU neonatal atlas template [2]. Probabilistic tractography was performed using 2 different approaches: 1) Using FSL's connectivity based seed classification tool [3] (i.e. seeding voxels of the CC), and 2) using MRtrix whole brain tractography [4]. In both cases, streamlines were terminated when attempting to cross the midline outside the CC mask, which was defined in JHU neonate space. Twenty-three cortical areas per hemisphere were extracted from the JHU neonatal atlas (Figure 1) and used as target areas for tractography.

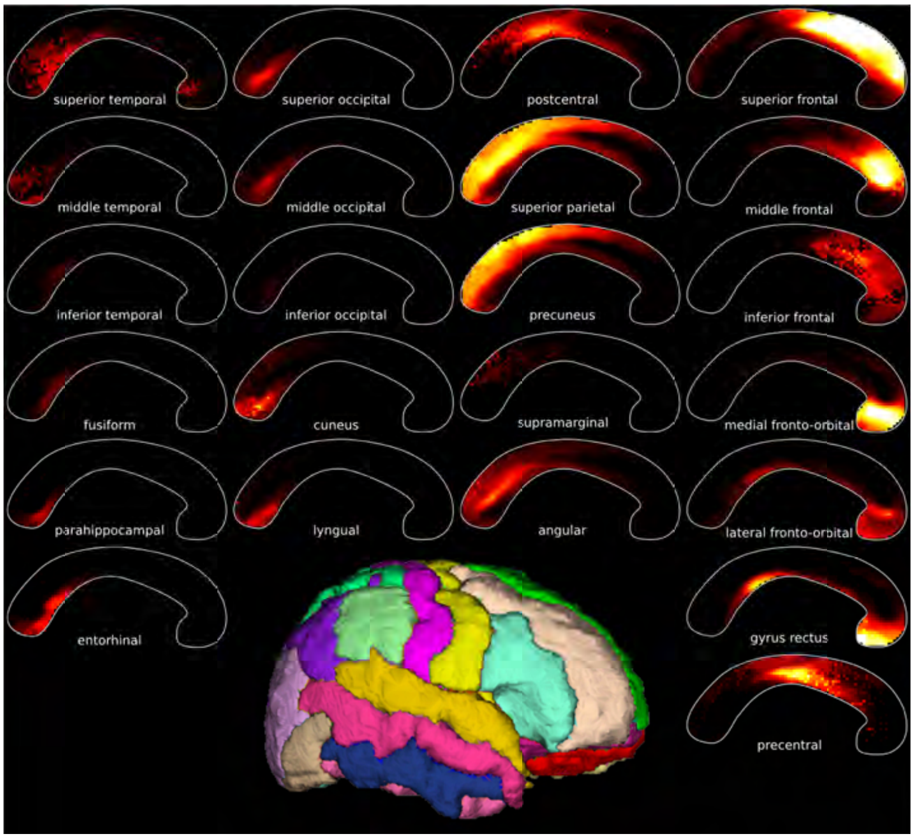

Figure 1: Population maps of the segmentation of the corpus callosum

Results: The CC was successfully segmented using tractography (Figure 1). Both approaches yielded similar segmentation results. Connections to frontal lobe subregions were found in the rostrum, genu, rostral body and anterior midbody of the CC. Precentral and postcentral connections were found in the anterior and posterior midbody. Connections to parietal subregions extend from the posterior midbody to the splenium, sharing the latter with occipital and temporal connections. Due to overlap of the segments, connectivity to temporal and occipital regions appeared weaker than connections to frontal and parietal regions.

Discussion: Diffusion tractography offers a non-invasive and fully automated method for segmenting the preterm CC at term equivalent age. Once segmented, summary measures of tract integrity (e.g. FA, MD) can be compared across cohorts and correlated with clinical scores. These partitions allow more detailed analysis than manual ROI analysis (where the corpus callosum is usually divided using geometric partitions). Furthermore, by using tractography, analysis is not restricted to the mid-sagittal plane, but can be extended to include the entire three-dimensional volume of the corpus callosum projections. Importantly, this automated approach can be used to assess early neonatal neurorehabilitation strategies.

References: [1] Thompson et al., 2011. Neuroimage 55: 479-490. [2] Oishi et al., 2011. Neuroimage 56: 8-20. [3] Smith et al., in press. Neuroimage doi:10.1016/j.neuroimage.2011.09.015. [4] Tournier et al., 2007. Neuroimage 35(4): 1459-1472