Measurement of white matter maturation in the preterm brain using NODDI.

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Target Audience: Researchers or clinicians with an interest in diffusion imaging as applied to a preterm neonatal cohort.

Purpose: Very preterm (VPT = <32 weeks completed gestation) infants are more likely to suffer from neurodevelopmental disabilities and recurrent health problems. Adverse outcome is associated with white matter damage as revealed by diffusion-weighted imaging (DWI) and the diffusion tensor (DT) model. However, a particular value of a DT parameter such as FA or MD can represent a range of microstructural conditions. Neurite Orientation, Dispersion and Density Imaging (NODDI) uses a multi-compartment model, with multi-shell acquisition, to fit more specific parameters relating to geometric properties and neuronal packing. This separates some of the contributors to the DT parameters and enables local microstructure to be inferred. This has been performed in the infant brain at term and this approach shows greater specificity than the DT model.

Using NODDI parameters, we investigated how microstructure changes in white matter regions of interest during the preterm period. The specificity of the parameters will aid in determining imaging biomarkers of cognitive health and facilitate earlier and more effective therapeutic intervention. To the authors’ knowledge, this abstract represents the first time that the longitudinal changes in these parameters have been mapped in the preterm population.

Methods: Eight VPT infants (26.3 ± 0.8 weeks gestational age (GA)) with normal cerebral ultrasound imaging were scanned soon after birth (32.4 ± 1.8 weeks GA) and at term equivalent age (44.2 ± 3.5 weeks GA). We acquired DWI in a 3T Philips MRI scanner with 6 volumes at b = 0s.mm-2, 16 at b = 750 s.mm-2, 32 at b = 2000 s.mm-2 (48 diffusion directions in total); resolution = 1.75x1.75x2.00 mm3, TR = 9s and TE = 60ms, total duration = 11m3s. We removed motion-corrupted volumes and eddy-current corrected the remaining data, rotating the b-vectors and modulating by the expansion/contraction of the transformation. We fitted the diffusion tensor using non-linear least squares. To identify the corpus callosum (CC), posterior and anterior limbs of internal capsule (PLIC/ALIC), we registered an FA atlas image to each infant non-linearly and propagated the labels with this transformation. These were adjusted manually.

We fitted the NODDI model in the regions of interest and evaluated the three microstructural parameters to cognitive tests undertaken during the first two years of life, we will determine more specific imaging biomarkers for future cognitive performance.

Conclusions: We have shown, for the first time, how NODDI parameters change in white matter regions of interest during 29-48 weeks EGA for the same infants. NODDI successfully disentangles microstructural contributions to the FA while still being performed within a clinically acceptable timeframe. By comparing microstructural parameters to cognitive tests undertaken during the first two years of life, we will determine more specific imaging biomarkers for future cognitive performance.


Table 1: Average values of diffusion parameters ± standard deviation. Green signifies a significant increase. ‘Preterm’ signifies the scan taken shortly after birth, ‘term’ means at term-equivalent age.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Region</th>
<th>FA at Term</th>
<th>FA at Preterm</th>
<th>ODI at Term</th>
<th>ODI at Preterm</th>
<th>( v_c ) at Term</th>
<th>( v_c ) at Preterm</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>0.27±0.02</td>
<td>0.33±0.03</td>
<td>0.10±0.02</td>
<td>0.09±0.02</td>
<td>0.15±0.02</td>
<td>0.22±0.04</td>
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<tr>
<td>PLIC</td>
<td>0.37±0.05</td>
<td>0.50±0.05</td>
<td>0.10±0.09</td>
<td>0.09±0.02</td>
<td>0.21±0.02</td>
<td>0.32±0.04</td>
<td></td>
</tr>
<tr>
<td>ALIC</td>
<td>0.18±0.04</td>
<td>0.25±0.03</td>
<td>0.21±0.05</td>
<td>0.21±0.05</td>
<td>0.14±0.02</td>
<td>0.22±0.04</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: CC (blue), PLIC (red) and ALIC (yellow)

Figure 2 a, b, c: Diffusion model parameters against post-conceptual age. Lines join the values for preterm and term scans of the same infant.