Early high b-value diffusion MRI of the preterm infant brain highlights radial organisation of the developing cortex
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Purpose
Diffusion MRI provides a powerful tool for the non-invasive assessment of brain maturation in preterm infants. The strength of diffusion weighting (b-value) and number of encoding directions play a crucial role in achievable angular resolution. The aim of this study was to investigate the effect of b-value and number of encoding directions on quantitative diffusion metrics in preterm infants scanned early in life.

Methods
Seven preterm infants born at less than 30 weeks gestation were included. MRI was performed during natural sleep between 30 and 34 weeks postmenstrual age using a 3T scanner with MR compatible incubator and neonatal head coil. Two diffusion MRI datasets were acquired for each infant: 1) using 30 directions at a b-value of 1000 s/mm², and 2) using 64 directions at a b-value of 2000 s/mm². Sets of 30 directions and 45 directions at a b-value of 2000 s/mm² were extracted from the 64-direction dataset acquired at a b-value of 2000 s/mm² using the electrostatic approach. Following preprocessing to reduce image artefacts related to head movement and susceptibility distortions, maps of fractional anisotropy (FA), mean diffusivity (MD), axial (Dax) and radial diffusivity (Drad) were calculated. Constrained spherical deconvolution was used to estimate fibre orientation distributions (FOD). The coherence of the direction of the first largest FOD peak was assessed by comparison with neighbouring voxels. Regions of interest were delineated manually for the splenium of the corpus callosum (SPL) and frontal lobe grey matter (FRT) based on colour-encoded FA maps as representative white and grey matter structures. Mean values of FA, MD, Dax, and Drad were extracted for each ROI, and compared across the different diffusion datasets using paired-sample Wilcoxon signed rank test.

Results
An example colour-encoded FA map for the different acquisition schemes is shown in Figure 1. Qualitatively, we observed an improved contrast of cortical grey matter at high b-value (see Figure 1). Quantitatively, comparing the two 30-direction datasets, FA was significantly increased at the higher b-value in the frontal grey matter (p=0.007), while no alteration was observed in white matter (Figure 2). This increase in FA in frontal grey matter was accompanied by a decrease in MD (p=0.001), Dax (p=0.01) and Drad (p=0.004). MD was reduced in the splenium (p=0.006), accompanied by a decrease in Dax (p=0.0006), and a decrease in Drad (p=0.0006). Changes in the coherence of the largest FOD peak were not statistically significant for any region. Increasing the number of directions did not result in significant changes in any diffusion metric at b = 2000 s/mm², however FOD coherence was improved in frontal grey matter regions (p=0.04), but not in white matter regions, with 64 directions compared to 30 directions.

Discussion
In agreement with a previous study in term infants, we found no change in FA, and an increase in MD, with increasing b-value in white matter. Within cortical grey matter regions, we observed a statistically significant increase in FA, and decrease in MD, with increasing b-value. The radial organisation of the developing cortex can be better appreciated at high b-values visually (Figure 1), and exhibits increased anisotropy. Our finding indicates that intra-axonal water diffusion is the major contributor to the observed diffusion anisotropy in the developing cortex. Furthermore, fibre coherence appeared improved at higher b-values (Figure 2).

Conclusion
Diffusion MRI at high b-values may provide further insight into the maturation of the cortical grey matter in preterm infants.

References