A pilot study of motion corrected DTI in the Fetal brain

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Background: Fetal diffusion tensor imaging offers the opportunity to provide detailed information on normal white matter development. The major limitation of fetal DTI is fetal movement, which is often not addressed in fetal MR studies [1,2,3]. The objective of the study was to 1) test an optimised fetal diffusion tensor imaging (DTI) protocol and algorithm for motion correction, 2) compare FA results obtained in utero to those obtained in preterm infants at a similar post-menstrual age (PMA).

Methods: All parents gave written consent prior to scanning. Fetal subjects were imaged on a 1.5T Philips Achieva system, with 32-channel cardiac coil; SENSE and sedation were not used. The imaging protocol for the fetus >30weeks PMA was as described previously: B_0 field map, TE_1=4.6ms, TE_2=9.2ms, TR=10ms, Flip Angle=10˚, Voxel Size (VS) = 2.27×2.27×10mm^3; spin Echo EPI images (b=0s/mm^2) and DTI images (b=500s/mm^2, 15 non-collinear directions), TE=121ms, TR=8500ms, FOV= 290×290×128mm^3, VS= 2.3×2.3×3.5mm^3, Gap=-1.75mm [4]. For fetuses <30 weeks PMA, the slice thickness was reduced to 3.3mm to improve the registration. In both protocols the diffusion gradient table was adjusted for scanner settings when calculating the diffusion tensor. The pipeline to calculate DTI metrics was: 1) distortion correct of all images in scanner coordinates using FSL FUGUE using the acquired field map [4]; 2) reconstruct a volumetric b_0 image using SVR[5]; 3) register DW images to a matched predicted DW volume generated from the b_0 volume using a current estimated DT[6]; 4) calculate DT at each voxel taking account of position and rotation of each slice. FA values obtained were compared to preterm infants (32 neonates who were scanned at 3T). Neonatal FA maps were produced using FSL4 [7]. Region of interest analyses were carried out in the splenium and genu of the corpus callosum and the posterior limb of the internal capsule (PLIC). Statistical analyses were performed using Stata/IC 11.

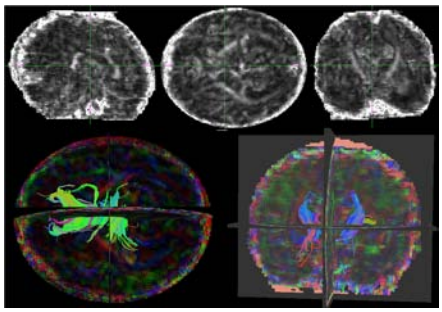

Figure 1: Fetus scanned at PMA 33^{+1} weeks. *Upper row:* FA map created with parameter-optimised algorithm. *Lower row:* DTI tractography depicts the cortico-spinal tract and corpus callosum tracts of the genu.

Results: 19 fetal FA maps were produced and analysed; of this group, 4 were healthy controls. There was no significant difference in PMA at scan between the fetuses and the preterm infants. Compared with our previous result [4], the revised model driven algorithm optimises the parameters in the registration and reduces artefacts in the final result, thereby producing improved quality FA maps (Figure 1). Fetal and neonatal FA values are detailed on Table 1. There were no significant differences between groups in any region. A significant increase in fetal FA values over PMA was found in the splenium (p=0.004; R^2=0.419) and the PLIC (p=0.002; R^2=0.448). These results are consistent with the preterm group results in these regions (splenium: p=0.023, R^2=0.161; PLIC: p<0.0001, R^2=0.586), as well as those reported in other preterm studies[8].

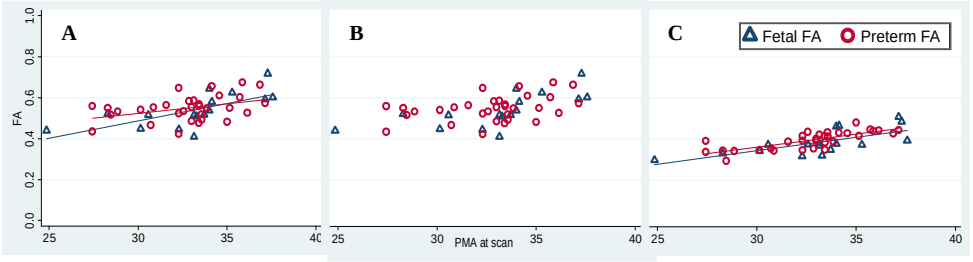

Figure 2: Graphs showing FA values versus PMA in fetal and preterm white matter. Significant increases in FA with increasing PMA were observed in the Splenium (A) and PLIC (C), but not in the genu (B) in both groups.

Table 1: FA data of fetal and preterm white matter and PMA

	FA	Fetus	Preterm
Splenium	Mean	0.54	0.55
	Range	0.41 - 0.72	0.42 - 0.67
Genu	Mean	0.49	0.51
	Range	0.38 - 0.59	0.43 - 0.58
PLIC	Mean	0.38	0.40
	Range	0.30 - 0.51	0.29 - 0.48
PMA at (weeks)	Mean	32.86	32.72
	Range	24.86 - 37.57	27.43 - 37.14

Conclusion: We have tested an optimised fetal DTI protocol and an algorithm for motion correction that allow us to generate improved quality fetal DTI. We have validated the results in a quantitative comparison with a PMA matched group of neonates. The FA values obtained in these 2 groups are similar, including trends with increasing age. The approach has the potential to explore brain development in the normal fetus, to study disease processes in utero and, by comparison to the normally developing fetal brain, to explore the onset and evolution of differences in white matter development associated with preterm birth.

References: [1] G. Kasprian et al., NeuroImage *43*:213-224 (2008). [2] E. Zanin et al., Brain and Behaviour, *1*(2):95-108 (2011). [3] T. Bui et al., Pediatr Radiol, *36*:1133–1140 (2006). [4] Z. Wu et al., ISMRM (2012). [5] S. Jiang et al., IEEE TMI, *26*(7):967-980 (2007). [6] A. Bertelsen et al., ISMRM (2009). [7] S.M. Smith et al., NeuroImage *23*(1):S208-219 (2004). [8] Partridge et al., NeuroImage *22*(3):1302-14 (2004).