Diffusion tractography in the preterm brain at 3 Tesla

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Introduction

Diffusion tensor imaging (DTI) studies have shown that the white matter in preterm infants develops differently to infants born at term.[1] In addition, recent work combining diffusion weighted imaging (DWI) and deformation based morphometry (DBM) has shown that abnormalities in the white matter are associated with abnormalities in central grey matter in this group of infants, and suggests that connectivity may be altered in the preterm brain.[2] Diffusion tractography offers the opportunity to explore the integrity of axonal connections *in vivo*, and so is an ideal tool for testing this hypothesis. Acquiring diffusion tensor imaging (DTI) data suitable for diffusion tractography is challenging in adults as good signal to noise ratio (SNR) and spatial resolution are required. These difficulties are compounded in infants, where motion artefact is frequently a problem, even when the infants are sedated for imaging, and so scan times of no longer than a few minutes are desirable. It is possible that these problems may be overcome in part by imaging at 3 Tesla. The higher SNR afforded by the higher field strength will enable high resolution imaging to be achieved in a limited time and so may be useful in obtaining data suitable for tractography in the preterm brain. The aims of this study were to determine whether it was feasible to perform diffusion tractography in the preterm brain and, if feasible, to examine changes in major white matter tracts associated with development.

Subjects

DTI was obtained on 10 preterm infants who were born at a median (range) gestational age (GA) of 27.86 (25.71 – 33) weeks and were imaged at a median post menstrual age (PMA) of 35.43 (29.86 – 47.14) weeks.

Methods

MRI was performed on a 3 Tesla Philips MR system using a phased array head coil. T2 fast spin echo (FSE) and 3D MPRAGE images were acquired prior to DTI. DTI was obtained in 15 non-colinear directions with a *b* value of 750 s/mm^2 using single shot EPI. The DTI sequence parameters were as follows; TR 9000ms, TE 79 ms, EPI train length = 59, 1 NSA, matrix = 112x 112, slice thickness = 2mm, FOV = 224, resultant voxel size = 2 x 2 x 2 mm^3. The data were acquired with a SENSE factor of 2. The scanning time for this sequence was 3 minutes and 27 seconds.

The DT images were corrected for eddy current distortions using affine registration. Diffusion tractography was performed using a linear propagation technique, fibre assignment by continuous tracking (FACT)[3] using DTI Studio version 2.1.[4] Two ROIs were determined for each tract studied. Fibre tracking was initiated from every imaging voxel in the brain, and tracts that went through both ROIs were taken to represent the fibre tracts. On the basis of the orientation of the eigenvector associated with the largest eigenvalue, tracts were propagated in both the orthograde and retrograde directions from the centre of seed voxels. Tracks were terminated when the propagated tract reached a voxel with FA lower than the stipulated threshold (0.20) and when the angle between the 2 principal eigenvectors of connected pixels was greater than 45^o. The corticospinal tracts, optic radiations, genu and splenium of the corpus callosum were examined. Values for axial diffusivity (λ_1), radial diffusivity ($(\lambda_2+\lambda_3)/2$), FA and ADC were obtained for each tract. Linear regression analysis was performed to test the relationship between diffusion measures and PMA at scanning for infants who had no evidence of abnormality on MRI.

Results

Nine preterm infants had no evidence of abnormality on MRI. One infant had a large right sided cystic lesion in the parietal white matter and abnormal signal intensity in the right posterior limb of the internal capsule (PLIC). We were able to track fibres in major white matter bundles in the preterm brain from 30 weeks PMA.

Change in axial diffusion, radial diffusion, FA and ADC with increasing PMA in preterm infants with no evidence of abnormality on MRI.

Corticospinal tracts - Axial diffusion ($p = 0.05$), radial diffusion ($p = 0.01$) and ADC values ($p = 0.01$) significantly decreased, and FA significantly increased ($p = 0.02$) with increasing PMA. Optic Radiations - Radial diffusion ($p = 0.02$) and ADC values ($p = 0.02$) significantly decreased and FA ($p = 0.02$) significantly increased with increasing PMA. Although axial diffusion decrease with increasing PMA, this change was not significant ($p = 0.08$). Genu of the corpus callosum - linear regression did not demonstrate any significant change with increasing PMA in axial diffusion ($p = 0.89$), radial diffusion ($p = 0.44$), FA ($p = 0.24$) or ADC values ($p = 0.87$). Splenium of the corpus callosum - linear regression did not demonstrate any significant change with increasing PMA in axial diffusion ($p = 0.93$), radial diffusion ($p = 0.60$), FA ($p = 0.24$) or ADC values ($p = 0.74$).

Corticospinal tracts in the infant with abnormalities in the white matter and PLIC on the right.

The values for radial diffusion (right = 1.011 ± 0.02, left = 0.919 ± 0.03 x 10^{-3}mm^2/s) appeared higher and FA appeared to be lower (right = 0.26 ± 0.05, left = 0.39 ± 0.10) in the right corticospinal tracts compared to the left.

Discussion

This study demonstrates that diffusion tractography is feasible in the preterm brain, from 30 weeks PMA, using high resolution DTI data acquired at 3 Tesla. The acquisition time for this sequence was under 4 minutes, for whole brain coverage, and so was suitable for imaging neonates, where lengthy scanning times are not practicable. These initial results suggest that diffusion tractography may be useful in quantifying the development of major tracts in the preterm brain. In addition, anomalies in tract development associated with pathology can be detected.

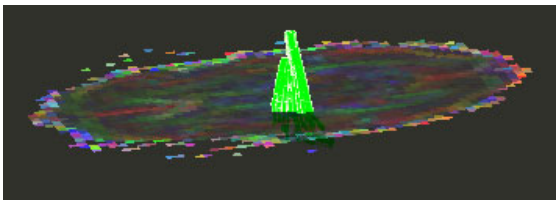

Figure 1. Right corticospinal tracts (shown in green) in an infant who was born at 27.86 weeks GA and imaged at 29.86 weeks PMA.

References

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