A preliminary investigation into high b value diffusion tensor imaging at 3 Tesla in the neonatal brain

S. J. Counsell[1], D. J. Larkman[1], O. Kapellou[2], D. Edwards[2], J. V. Hajnal[1], M. A. Rutherford[1]

[1]Robert Steiner MR Unit, Imaging Sciences Department, Clinical Sciences Centre, Hammersmith Hospital, Imperial College London, London, United Kingdom, [2]Department of Paediatrics, Hammersmith Hospital, Imperial College London, London, United Kingdom

Introduction

Diffusion weighted imaging with *b* values over 2000 s/mm^2 has been performed in animal studies (1) and, more recently, in the adult brain (2,3). These studies suggest that diffusion contrast characteristics are altered at higher *b* values and that diffusion in brain tissue is not monoexponential. In addition, it is possible that diffusion imaging at high *b* values enhances contrast between lesions and normal tissue, and thereby increases lesion conspicuity. To our knowledge, high *b* value diffusion tensor imaging (DTI) has not previously been performed in the neonatal brain. This may in part be because signal to noise ratio (SNR) is too low at high *b* values to provide useful diffusion images in an acceptable scanning time and resolution. It is possible that the increased SNR provided by imaging at 3 Tesla enables high *b* value DTI to be obtained in neonates.

Aims

1.To determine whether the high SNR afforded by imaging at 3 Tesla allows high *b* value DTI to be performed in the neonatal brain. 2.To assess whether apparent diffusion coefficient (ADC), fractional anisotropy (FA) or image contrast in the neonatal brain changes at high *b* values.

Methods

Ethical permission for this study was granted by the Research Ethics Committee at the Hammersmith Hospital. Single shot echo planar imaging DTI was acquired in 6 non-colinear direction on a Philips 3 Tesla Intera system with *b* values of 350, 700, 1500 and 3000 s/mm^2. The pulse sequence parameters used were as follows; TR 5000ms. TE 100ms, slice thickness 4mm, FOV 220mm, matrix 96 x 96 (acquired voxel size = 2.3 x 2.3 x 4; reconstructed voxel size = 1.7 x 1.7 x 4mm). NSA was increased with increasing *b* value; NSA = 2 (*b* 350 s/mm^2), 4 (*b* 750 s/mm^2), 6 (*b* 1500 and 3000 s/mm^2). DTI was performed on 3 neonates (3 days, 7 days and 40 days of age) who were undergoing MRI for clinical reasons. In addition, DTI was obtained using a phantom containing distilled water at 22^{o}C and a solid fat phantom.

Data Analysis

Isotropic diffusion weighted images, ADC maps and FA maps were calculated using Philips propriety software. Phantom data – measurements were taken from a circular region of interest (ROI) measuring 740mm^2. In order to assess hardware or pulse sequence errors, ln signal intensity was plotted against *b* value. Low *b* values were assessed using the water phantom, and high *b* values using the solid fat phantom. Neonatal data – ROIs were positioned in the thalamus, central white matter at the level of the centrum semiovale and the posterior limb of the internal capsule (PLIC). ADC and FA were plotted against *b* value.

Results

Phantom data showed no systematic change in ADC or FA over the range of *b* values.

Infant data - Isotropic diffusion images; at *b* = 350 s/mm^2 unmyelinated white matter is high signal intensity relative to central grey matter and the cortex. Highly anisotropic white matter regions such as the PLIC are not demonstrated as high signal intensity. At b = 700 s/mm^2 there is little contrast between unmyelinated white matter and central grey matter. At b = 1500 s/mm^2 unmyelinated white matter is low signal intensity relative to central and cortical grey matter. Highly anisotropic white matter regions are slightly hyperintense relative to both grey matter and unmyelinated white matter. At b = 3000 s/mm^2 unmyelinated white matter is extremely low signal relative to central and cortical grey matter. Highly anisotropic white matter fibre bundles are hyperintense relative to other brain tissues. Figure 1 shows isotropic diffusion weighted images at the basal ganglia level for the 4 different *b* values. ADC values decreased with increasing *b* value in all regions measured. In white matter there was an approximately linear trend in ADC versus *b* value, whereas in grey matter ADC declined more slowly at higher *b* value. This was particularly pronounced in the thalamus. Figure 2 shows change in ADC with *b* value. FA did not change with increasing *b* value, although the data was less consistent than the ADC results.

Discussion

This pilot study shows that good quality high *b* value DTI can be performed in the neonatal brain at 3 Tesla. As in adult studies (2), our initial results suggest that FA values are not altered by increasing *b* value, but ADC values in the white matter and central grey matter decease with increasing *b* value. In the thalamus this decrease appeared to be non-linear. Isotropic diffusion image contrast increases with increasing *b* value, which may have an important clinical utility in identifying lesions and assessing maturation in the neonatal brain.

References

1.Niendorf T et al. Magnetic Resonance in Medicine, 1996; 36: 847-857. 2.Yoshiura et al. Magnetic Resonance in Medicine, 2001; 45: 734-740. 3.DeLano et al. AJNR, 2000; 21: 1830 – 1836.

Acknowledgements

Philips Medical Systems, Medical Research Council, Academy of Medical Sciences, The Health Foundation, Garfield Weston Foundation.

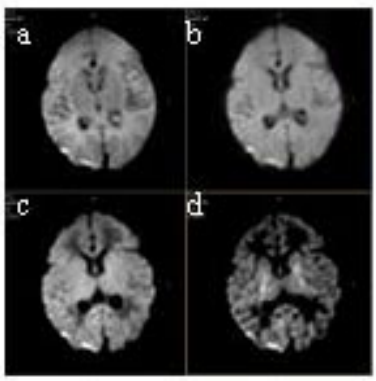

Fig 1a) b=350, b) b=700, c) b=1500, d) b=3000s/mm^2

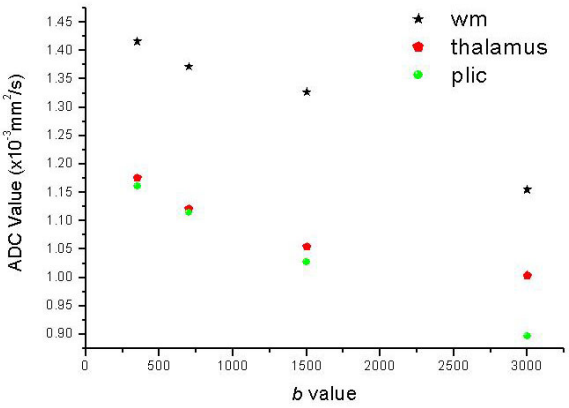

Fig 2. Graph of ADC versus *b* value