What b-value should be used to resolve crossing fibres in the neonate brain?

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Introduction: Diffusion MRI (dMRI) is particularly suited for studying white matter (WM) maturation in the premature and neonate brain, because it allows the non-invasive assessment of WM integrity as well as delineation of WM pathways using tractography *in vivo*. The *b*-values used for neonatal dMRI are generally lower than those used for adult dMRI due to the high water content of the newborn brain. According to [1], the optimum *b*-value for the measurement of apparent diffusion coefficient (ADC) can be estimated as $b = 1.11/ADC$. This *b*-value has been adopted for diffusion tensor imaging (DTI), and is approximately 700 s/mm^2. However, to enable the resolution of crossing fibres, higher order models of diffusion (e.g. high angular resolution diffusion imaging [HARDI]) have recently been developed, which require generally a higher *b*-value to achieve higher angular resolution. In this study, we assess the performance of two different higher order models of diffusion at 3 *b*-values. Due to difficulties associated with the lengthy image acquisition of multiple diffusion sequences in non-sedated term neonates, a piglet model was chosen for initial evaluation.

Methods: *Imaging:* A healthy newborn piglet was scanned using a 3T scanner. Diffusion imaging was performed along 64 non-collinear directions at *b*-values 700 s/mm^2 (typical neonatal DTI), 3000 s/mm^2 (typical adult HARDI) and 1500 s/mm^2 (intermediate *b*-value). *Constrained spherical deconvolution (MRtrix,*[2]*):* Residual bootstrapping based on spherical deconvolution [3] was used to generate 1000 artificial datasets for every *b*-value. The fibre orientation distribution (FOD) was estimated using constrained spherical deconvolution [2] at harmonic degree 8 for every artificial dataset. The 3 largest maxima were identified within every voxel, and the cone of uncertainty [4] calculated separately for each maximum across the 1000 bootstrap datasets. *Bayesian approach (FSL,* [5]*):* bedpostx was used to draw 1000 samples (total 2500 jumps, sampling every 25 jumps) after a burn-in of 1000 jumps, building the posterior distribution of fibre orientations at a maximum of 3 fibres per voxel. The cone of uncertainty [5] across all 1000 samples was calculated for every fibre orientation separately.

Results: Histograms and cumulative distribution plots of the cone of uncertainty are shown in Figure 1. Fibre orientations appeared to be better defined at a *b*-value of 1500 s/mm^2 compared to 700 s/mm^2 and 3000 s/mm^2 for both diffusion models, indicated by an increased frequency at lower cone-of-uncertainty values, although this finding was more pronounced for FSL.

Discussion: Even though the optimal b-value will be dependent on acquisition parameters and brain maturation, the findings from this study suggest that the b-value generally used for DTI (700 s/mm^2) may not be optimal for resolving crossing fibres, which is an important consideration for tractography studies. Among the three *b*-values used in this study, a *b*-value of 1500 s/mm^2 showed the best definition of fibre orientations (i.e. lowest cone of uncertainty). To further optimize this parameter, experiments using additional b-values are required. It is important to note that the analysis in this study was restricted to a maximum of 3 fibre orientations per voxel, regardless of *b*-value. It is conceivable that a higher number of fibre orientations may be resolved at the optimum *b*-value. Hence, enforcing a lower number of fibre orientations might cause an artificial increase in uncertainty as distinct fibre orientations are combined. This possibly explains the similarities in the cone of uncertainty distributions observed with MRtrix, where more than 3 fibre orientations were found in a number of voxels. The influence of the *b*-value on the number of fibre orientations that can be discerned, and subsequently the uncertainty in these fibre orientations, is currently under investigation. We recommend conducting similar investigations in the planning stages of neonate dMRI studies.

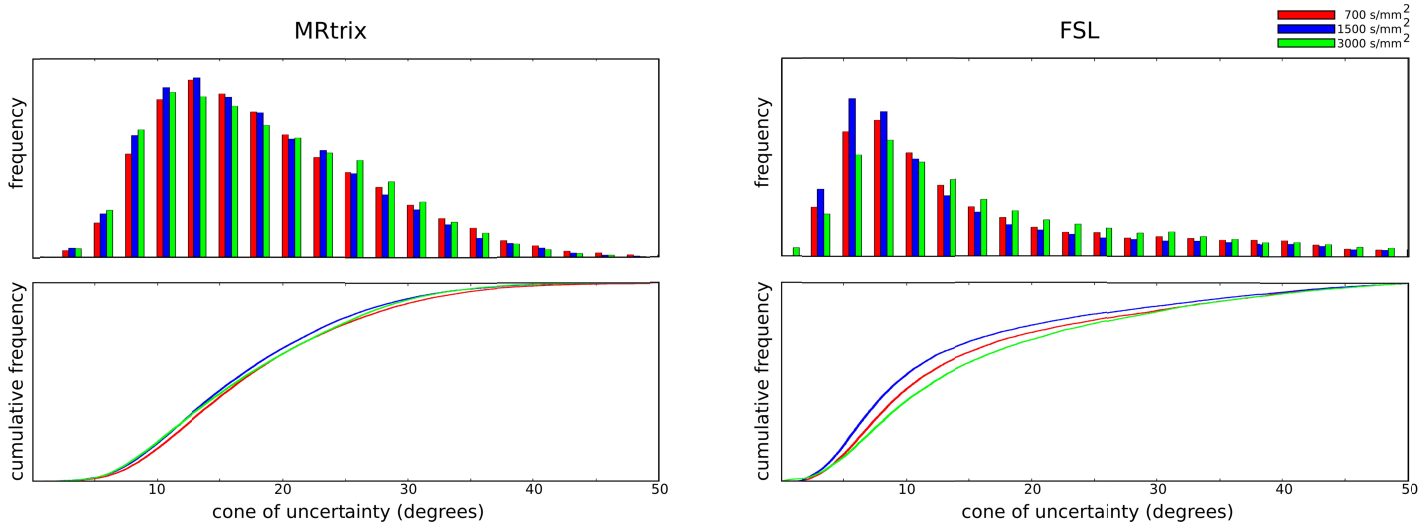

Figure 1: Histogram and cumulative distribution plot of the cone of uncertainty.

References:

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