

T2* measurement of fetal brain using a motion tolerant method

Serge Vasylechko¹, Christina Malamateniou², Rita Nunes^{2,3}, Matthew Fox², Joanna Allsop², Mary Rutherford², Daniel Rueckert¹, and Joseph Hajnal²
¹Biomedical Image Analysis Group, Department of Computing, Imperial College, London, United Kingdom, ²Division of Imaging Sciences and Biomedical Engineering, King's College, London, United Kingdom, ³Institute of Biophysics and Biomedical Engineering, University of Lisbon, Lisbon, Portugal

Introduction

Brain tissue T2* values are sensitive to changes in chemical composition and metabolic modifications that accompany cerebral growth and pathological processes. This time constant also defines an optimal setting for echo time when measuring BOLD fMRI response. The aim of this study was to determine T2* values for the fetal brain and to compare them with those of similar age pre-term and term born neonates. The biggest challenge of fetal scanning is unpredictable and uncontrollable fetal motion. The extent of movement means that conventional multi-shot acquisition techniques used in adult studies of T2* relaxometry would not be practical. We have explored the use of single shot multi-echo echo planar imaging (EPI) as a rapid method for measuring fetal T2* by effectively freezing intra-slice motion. Knowledge of standard fetal T2* values will help with image interpretation, protocol adjustment and assessment of maturation and abnormalities in fetal brains as well as parameter optimisation for fMRI.

Method

To obtain multi-echo images a standard field echo EPI sequence was modified to achieve multiple whole image readouts following a single radio-frequency pulse. Parameters were optimized for an acquisition on a Philips 1.5T scanner with a 32 channel cardiac coil. The resulting sequence provides whole head coverage, producing a set of 5 spatially aligned images per anatomical slice with an echo time range of 27-199.8ms (FOV =290x290 mm², SENSE factor 2, isotropic 3mm³ resolution, 10 000ms TR, 43.2ms inter-echo spacing, 90° flip angle, Spectral Presaturation with Inversion Recovery fat suppression). To determine T2*, nonlinear, weighted exponential curve fitting was applied using a Levenberg-Marquardt algorithm in Matlab 7.13. Scans were obtained on 5 fetuses; two were classified as normal, one twin pregnancy, one ventriculomegaly and one fetus with toxoplasmosis. Signal was measured over 4 cerebral regions of interest (ROI): medial occipital lobe (MOL), lateral occipital lobe (LOL), thalamus (Tha) & frontal white matter (FWM). Each ROI consisted of 3-5 voxels measured over multiple slices using 3 repeat scans to ensure stability. As a result, 18 voxels were averaged per subject per reported ROI. All subjects were examined with research ethics approval.

Results

There was substantial movement during the examination in each case, with fetuses typically moving by more than a slice thickness. An example slice is shown in the figure with its T2* map. The table presents the ROI data. Brain average fetal T2* was 194ms (+/- 17ms) at the mean age of 28.8 weeks, which is consistent with previously reported pre-term neonatal measurements at 193ms for 30.8 weeks¹ and 162ms at 33 weeks². It is also significantly higher than the value of more mature brains at 42 and 43.5 weeks^{2,1}.

Conclusion

We have presented a robust method for T2* relaxometry in fetuses. The method requires long T2* decay constants but provides whole head coverage and is highly motion tolerant. Obtained T2* values are consistent with pre-term infants of similar age. Changes in T2* with age are thought to be related to increases in synaptic density, myelination and cerebral blood flow, all associated with brain development. The study data suggests that longer than usual TE values or direct T2* measurement should be considered when performing fetal fMRI. A larger number of subjects will need to be studied for a more thorough quantification of T2* during fetal brain growth.

References

- 1) Lee W et al., Develop med & child neurology, 2012; 54, 724-9
- 2) Rivkin MJ et al., Magn Reson Med, 2004; 51, 1287-91

Table: Comparison of reported T2* values (in ms) according to fetal/infant age.

Scan	Fetal	Preterm neonatal		Term neonatal	
Study	Our study	Lee ¹	Rivkin ²	Rivkin ²	Lee ¹
Age/weeks	29.3 (SD 5.5)	30.8 (SD 2.2)	33 (SD 0.6)	42 (SD 0.9)	43.5 (SD 1)
MOL	189 ± 36	187 ± 54	142 ± 30	132 ± 37	111 ± 12
LOL	197 ± 40	198 ± 44	155 ± 49	151 ± 36	133 ± 17
Tha	176 ± 43	-	137 ± 13	127 ± 23	-
FWM	211 ± 66	-	180 ± 38	152 ± 51	-
Average	194 ± 17	193 ± 8	162 ± 51	142 ± 36	122 ± 16

Figure: Reconstructed EPI images echoes 1-5 and the associated T2* map.

