Gradient Echo Plural Contrast Imaging in Studying Neonatal Brain Development: Preliminary Results

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Purpose: Different methods have been used in the past to study brain development, e.g. (1, 2). Gradient Echo (GR) experiments have drawn attention in recent years not only because they are much faster than conventional Spin Echo (SE) experiments, but also due to their ability to provide information on tissue-specific properties. This allows introduction of additional bio-markers such as tissue T2* relaxation time and frequency. Gradient Echo Plural Contrast Imaging (GEPCI) is a new technique that allows generation of naturally co-registered images with various contrasts simultaneously (3-5). The resultant T2* and frequency maps are quantitative. With these features, GEPCI has already demonstrated advantages for evaluation changes in tissue structure in multiple sclerosis (4-7) and is suitable for monitoring other CNS diseases. Here, we present preliminary results for using GEPCI to study brain development in human neonates.

Methods: All studies were approved by the local IRB. Images were collected using a 3T Trio MRI scanner (Siemens, Erlangen, Germany). Datasets with high resolution ($1\times1\times3$ mm^3) were collected from 3 neonatal subjects (subject 1: born prematurely at 26 weeks, scanned at 38 weeks postmenstrual age (PMA); subject 2: term-born at 37 weeks gestational age, scanned at 38 weeks PMA; subject 3: term-born at 40 weeks gestational age, scanned at 40 weeks PMA). A two dimensional (2D) multi-slice-multi-gradient-echo sequence with a flip angle of 30° was used to acquire data. The total acquisition time for each scan was about 2 min. For each acquisition, 11 echoes were collected with first echo time TE1 = 4 ms and echo spacing ΔTE = 4 ms. The last echo was used as a navigator echo by applying additional magnetic field gradients to unwind the spatial encoding gradients before it. Multiple-contrast GEPCI images were reconstructed using algorithms developed in (5) and the voxel spread function (VSF) method for macroscopic field inhomogeneity correction (8).

Results: Fig. 1 compares clinical T2-weighted images with GEPCI-T2* maps. T2* maps show stronger contrast and more detail compared with conventional T2-weighted images. Frequency maps and GEPCI-SWI images provide detailed information on blood vessels that can be used to monitor the development of blood vessels in neonatal brain. Fig. 2 shows R2* distributions of three neonatal subjects, with one healthy adult subject for comparison. These distributions show substantial differences between neonatal and adult brain, most likely reflecting difference in myelination. Subjects 2 and 3 are both term-born and their R2* distributions look similar. However, the R2* distribution of subject 3 (Fig. 2) is slightly shifted to the right (high R2*), which indicates higher myelination level for this subject. Importantly, the R2* distributions differ between the term-born control infants (subjects 2 and 3) and the preterm infant studied at term-equivalent PMA (subject 1). Though subject 1's conventional MRI was read as normal, the different R2* distribution may indicate some degree of injury not detected on conventional MRI.

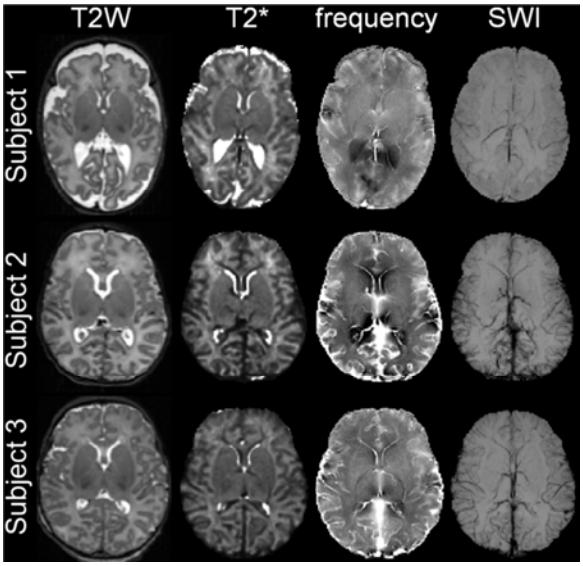

Fig. 1 Comparison of clinical T2-weighted images and GEPCI-derived multi-contrast images (T2*, frequency and SWI).

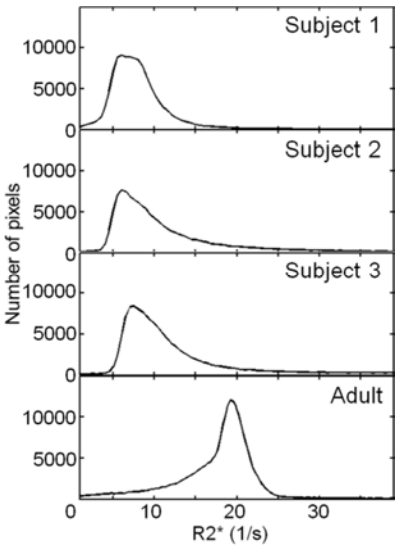

Fig. 2 Comparison of R2* distributions of three neonatal subjects and one healthy adult.

Conclusion: We demonstrate the feasibility of applying the GEPCI technique to the evaluation of brain development. By generating multi-contrast within a single fast scan, it not only reduces artifacts due to subject motion, but also provides a multi-perspective means by which to explore neonatal brain development and injury quantitatively.

References: (1) Neil JJ et al., Journal of Child Neurology (2006), 21: 115-118; (2) Kroenke CD et al., MRM (2006), 55: 187-197; (3) Yablonskiy DA., Proc. ISMRM (2000), 8: 431; (4) Sati P. et al., NeuroImage (2010), 51: 1089-1097; (5) Jie Luo et al., NeuroImage (2012), 60: 1073-1082; (6) Jie Luo et al., Multiple Sclerosis Journal (2013), DOI: 10.1177/1352458513495935; (7) Yablonskiy DA., PNAS (2012), 109: 14212-14217; (8) Yablonskiy DA et al., MRM (2013), 70: 1283-1292