Oscillating Gradient Spin-Echo (OGSE) Diffusion Tensor Imaging of the Human Brain
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**Purpose.** In the brain, water diffusion is restricted by the presence of cellular membranes and other components. Accordingly, apparent diffusion coefficients (ADCs) depend on the time allowed for the molecules to probe the local environment; namely, the "diffusion time" (\(t_D\)). DTI is typically performed using pulsed gradient spin-echo (PGSE) diffusion encoding, which has an inherently large \(t_D\) (Fig 1). The oscillating gradient spin-echo (OGSE) method enables greatly reduced \(t_D\) (Fig 1), which grants a greater sensitivity to diffusion restriction/hindrance over smaller length scales \([1]\). A dependence of ADCs on \(t_D\) has been shown in mouse brain, with larger ADC (both parallel and perpendicular) and smaller FA observed for smaller \(t_D\) \([2]\). There is only one human study utilizing OGSE \([3]\), where perpendicular ADC determined using a tetrahedral scheme (\(b = 150\) s/mm\(^2\)) increased with decreasing \(t_D\) (10-4 ms) in the white matter of 2 subjects. The purpose of this work was to investigate the \(t_D\) dependence (5-40 ms) of the full diffusion tensor in white matter of healthy subjects by comparing OGSE and PGSE DTI (\(b = 300\) s/mm\(^2\)).

**Methods.** Four DTI protocols were acquired in 5 human subjects on a Varian Unity Inova 4.7 T MRI using \(t_D = 5\) ms (OGSE 50 Hz), 10 ms (OGSE 25 Hz), 20 ms (PGSE), and 40 ms (PGSE). Each protocol used: TR = 12.5 s; TE = 110 ms; FOV = 24 cm; 2 mm x 2 mm acquired in-plane resolution; 40 slices, thickness 2.5 mm; 6 averages; R=2 GRAPPA; 60 mT/m gradients; \(b = 300\) s/mm\(^2\); scan time 10 min each. ExploreDTI was used for tractography using an FA threshold of 0.3 and angle threshold of 30°. The splenium (~2 cm central portion) and corticospinal tracts (from brainstem to internal capsule) were analyzed. The data from the 4 scans were motion corrected relative to each other using in-house software, and voxels for analysis were chosen using the tract mask obtained from the \(t_D = 40\) ms scan. Statistical significance of overall \(t_D\)-dependence was evaluated using a repeated measures ANOVA, and changes with respect to the \(t_D = 40\) ms scans were evaluated using paired t-tests.

**Results and Discussion.** Even with a low \(b\) value of 300 s/mm\(^2\) (and high SNR of 39 in splenium on b0 images), DTI images and tracts were of good quality (Fig 2) and qualitatively similar for all diffusion times for either OGSE or PGSE. Quantitative analysis over the tracts showed statistically significant variations of DTI eigenvalues (both parallel, \(\lambda_{||}\), and perpendicular, \(\lambda_{\perp}\)) and FA, where ADC increased and FA decreased as \(t_D\) decreased in both the corticospinal tract (\(\lambda_{||}: +10\%, \lambda_{\perp}: +24\%,\) FA: -6%) and splenium (\(\lambda_{||}: +9\%, \lambda_{\perp}: +14\%,\) FA: -3%) (Fig. 3). A notable greater % increase of \(\lambda_{\perp}\) is observed compared to \(\lambda_{||}\), and these changes mirror results observed in animal models \([2]\). As expected, no significant variation with respect to \(t_D\) (i.e. \(p_{\text{ANOVA}} > 0.05\)) was observed in the water phantom (Fig. 3).

**Conclusion.** OGSE has demonstrated diffusion time dependencies of the diffusion tensor for the first time in humans. The ability to target different length scales via the diffusion time may improve sensitivity to changes in tissue microstructure.