Mapping longitudinal white matter changes in extremely preterm born infants

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Synopsis: During the preterm period, the brain undergoes changes in volume, structure and cortical folding, which can be connected with cognitive abilities in preterm born infants. Diffusion MRI allows us to investigate microstructural changes during this period. In this study we registered the longitudinal diffusion tensor images of six extremely preterm born infants and looked at white matter changes. The corpus callosum and internal capsule exhibits the most microstructural changes during this crucial period and we hypothesis that this can affect the neurodevelopment in these infants.

Purpose: Infants that are born extremely preterm, before 27 weeks of gestation, are at higher risk of developing cognitive and neurological impairment [1]. During this crucial period, the brain undergoes significant changes in volume and cortical folding, but also on the microstructural level, especially in the white matter. All of these changes have been shown to be correlated with cognitive ability, thus mapping them may provide us potential biomarkers of cognitive ability[2]. Diffusion MRI is sensitive to motion of water on the scale of microns and allows us to investigate the microstructural changes that are taking place over the preterm period. Registration of diffusion tensor images when deformations are very large is extremely challenging and classical tensor registration techniques do not manage to cope with the large deformations that are taking place, as it happens during the preterm period.

Methods: We acquired longitudinal diffusion-weighted data at a resolution of *0.82 mm x 0.82 mm x 0.5 m* from six preterm-born infants with mean gestational age at birth of 26.2 weeks. We acquired six volumes at $b = 0\ s/mm^2$, 16 directions at $b = 750\ s/mm^2$ and 32 at $b = 2000\ s/mm^2$ with TR/TE = 9s/60 ms. Each infant was scanned twice, once shortly after birth at an average equivalent gestational age (EGA) of 31.4 weeks and then around equivalent term at average EGA of 42.8 weeks. We registered the diffusion tensor images (DTI) of all subjects longitudinally, term to preterm scan, using first a global diffusion tensor spectral matching algorithm (TSM) [3] followed by a local refinement using DTI-TK [4]. TSM was shown to be successful in performing an initial global alignment of tensor images even when there are large deformations taking place. The pipeline is described in Figure 1.

We performed a groupwise registration of all preterm DTIs, using a linear affine registration followed by the same TSM-DTI-TK framework, to create an average atlas. We then mapped all individual longitudinal changes into the atlas space to investigate microstructural changes during the preterm period.

To investigate the longitudinal microstructural changes in the same common space, we looked at the changes in the deformation field after longitudinal registration in the common groupwise space in the white matter, segmented using a neonate specific segmentation framework [5].

Results: The longitudinal deformation fields were brought into the groupwise space. The longitudinal changes in deformation field magnitude follow similar patterns, with larger deformations in the corpus callosum and internal capsule in all infants (Figure 2). The changes in the white matter regions seem to be linearly correlated with the time difference between scans. Considering a linear constant change over time in the white matter structures, we can estimate an average rate of change per week from the magnitude of the deformation field by averaging the changes in all infants and correcting for scan time. From the map of average rate change in white matter structures (Figure 3), we notice again that the internal capsule and corpus callosum develop the most in structure during the preterm period.

Discussion/Conclusion: In this work we successfully registered longitudinal diffusion tensor images of six extremely preterm born infants scanned shortly after birth and at equivalent term time. Using the same framework, we also created an average early time point scan to map all the changes in the same space. We notice that microstructural changes are consistent among infants and the most changes during the preterm period take place in the corpus callus and internal capsule. Hence, these regions are likely to be affected by preterm birth and influence neurodevelopment in extremely preterm born infants. Our further work will include quantification of the white matter changes as well as their correlation with the psychological outcome of the infants.

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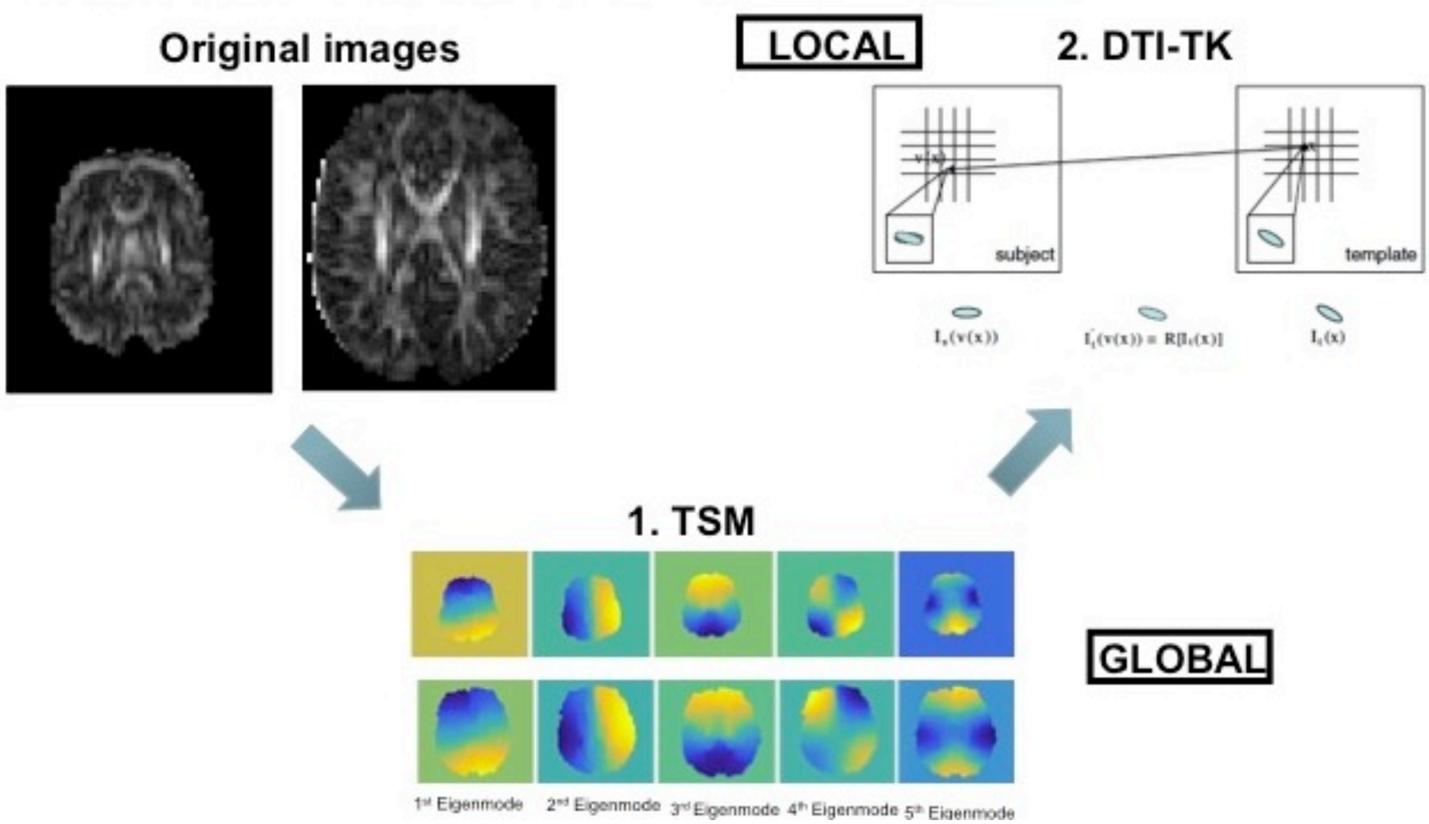

Figure 1. Longitudinal registration framework for diffusion tensor images of extremely preterm born infants

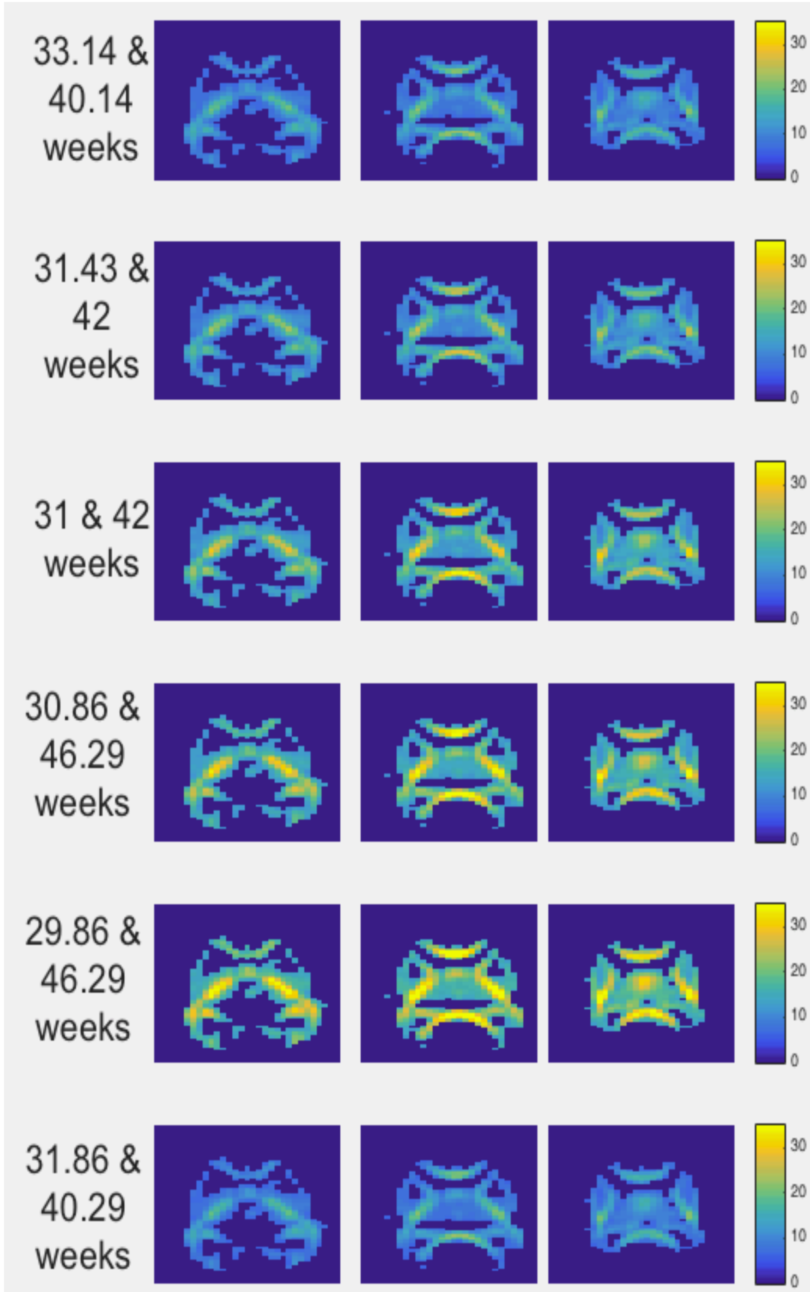

Figure 2. Longitudinal changes in white matter diffusion tensor images at three different axial views

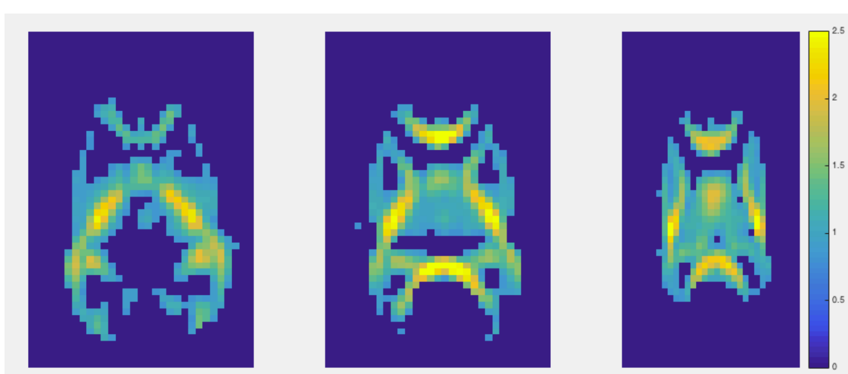

Figure 3. Rates of longitudinal changes in white matter diffusion tensor images at three different axial views. Units are mm/week.