MRI Diffusion Tensor Tractography for Quantitative Assessment of White Matter Pathways in Newborns with Congenital Heart Disease

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Introduction: Pre-operative brain injury (stroke and white matter injury) has been identified in newborns with congenital heart disease (CHD), a population at high risk of neurodevelopmental impairment [1]. Given the high incidence of pre-operative brain injury, serially studied term newborns with CHD provide an opportunity to study the effect of early injury on subsequent neonatal brain development. MR diffusion tensor imaging (DTI) identifies developmental changes in neonatal white matter (WM) and gray matter microstructure [2]. DTI fiber tractography (DTT) enables the 3D segmentation of axonal bundles, based on preferential direction of water diffusion along axons, allowing quantitation of DTI parameters in specific WM pathways [3,4]. Our purpose was to investigate pyramidal tract development in newborns with CHD using pre- and post-operative DTI and tract-based quantitation of fractional anisotropy (FA) and directionally-averaged apparent diffusion coefficients (D_{av}).

Materials & Methods: Twenty-seven term newborns with CHD (20 Transposition of the Great Arteries, 7 other) undergoing corrective cardiac surgery in the neonatal period were studied with MRI and DTI pre- and post-operatively at a median of 6 (range, 1 to 36) and 17 (range, 7 to 46) days of age respectively. Seven newborns had focal or multifocal injury on preoperative MRI: (3) stroke and (4) focal WM injury. Imaging was performed at 1.5T using an MR-compatible incubator with a high-sensitivity neonatal head coil [5]. DTI was acquired with a 4.8min single-shot, multi-repetition echoplanar sequence; TR/TE = 7s/100ms, 3 NEX, 256 x 128 matrix, 360x180mm FOV, 3mm slice thickness, no gap. Diffusion gradients were applied in 6 directions with b= 0 and 700s/mm^2. DTT fiber tracks originating in cerebral peduncle were filtered through the internal capsule and centrum semiovale to segment pyramidal tracts (**Fig. 1a**); FA and D_{av} were measured on images from voxels containing fiber tracks (**Fig. 1b**).

Figure 1

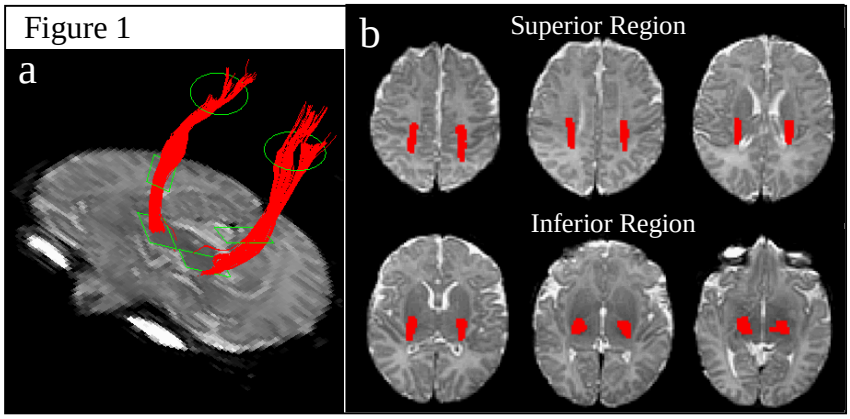

Figure 1. DTT segmentation of pyramidal tracts in a 25-day old neonate with congenital heart disease (a). The voxels containing fiber tracks in each slice (b), shown in red, were used for quantitation of DTI parameters.

Figure 2

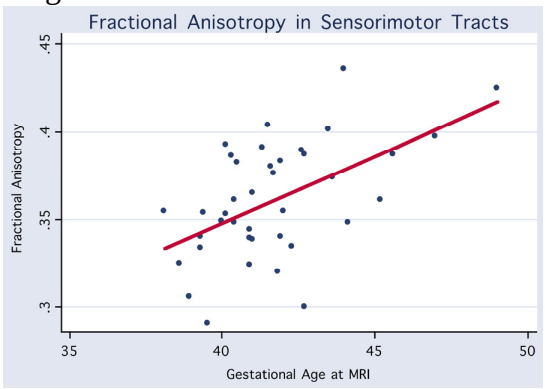

Figure 2. Serial FA measures of the pyramidal tracts in newborns with no brain injury showed significant maturational increases with age (median, 4.1%/week).

Results: On preoperative MRI exams, the pyramidal tracts had a median FA of 0.35 (0.29 to 0.40) and median D_{av} of 1.17 mm^2/s (1.05 to 1.33). Even with the short time period between serial exams in the study (median, 2 weeks), infants without injury showed increasing FA with age (**Fig. 2**), median 4.1% per week (-6.9 to 19.9%), and decreasing D_{av} with age, median –2.8% per week (-11.9% to 0.9%). In contrast, infants with injury had less dramatic changes with age: median FA increase of 0.9% (-2.4 to 3.3%), and median D_{av} decrease of –1.0% (-5.3 to 1.0%) per week. The reduced maturational FA change in infants with injury compared to those without was significant (p = 0.046, Mann-Whitney test), and the D_{av} change showed a trend of being reduced (p = 0.06) in the infants with injury. The earlier maturing inferior region of tract (between the cerebral peduncle and internal capsule, **Fig 1b**) demonstrated higher FA (median, 0.39) and lower D_{av} values (median, 1.10 mm^2/s) in preoperative exams compared with the superior portion of tract (median FA = 0.33, median Dav = 1.23 mm^2/s), but both regions showed similar maturation trends of increasing FA and decreasing D_{av} with age.

Discussion: These preliminary data suggest that DTT can be used to characterize the development of specific WM tracts in newborns following acquired brain injury. Further investigation is needed to determine whether maturational changes measured in specific WM tracts may help assess risk of specific neurodevelopmental impairments (e.g. motor skills) in newborns with early brain injuries.

References:

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