Mapping of Paediatric Motor Function and Structure using Magnetoencephalography (MEG) and Diffusion Tensor Imaging (DTI)

D. Mabbott[1,2], W. Gaetz[1,3], E. Widjaja[3], S. Bells[1], and C. Rockel[1]

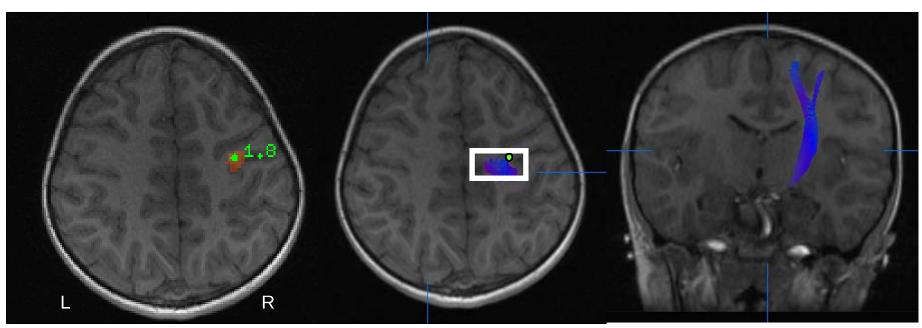
[1]Program in Neuroscience and Mental Health, The Hospital for Sick Children, Toronto, Ontario, Canada, [2]Paediatrics, University of Toronton, Toronto, Ontario, Canada, [3]Diagnostic Imaging, The Hospital for Sick Children, Toronto, Ontario, Canada

Introduction and Purpose: Maturation of functional neural pathways, including cortical activations and associated white matter connections, very likely mediates behavioral development in young children. Few studies examining brain/behavior relations have integrated functional and structural measures to examine developmental change, however. Lateralization of motor function (i.e., hand dominance) is an excellent model to examine such change. The development of hand dominance likely involves differential maturation of eloquent cortex and associated cortico-spinal tracts for the dominant versus non-dominant hand. In the past, mapping cortical motor fields in young children and identifying the functional white matter pathways associated with those fields has proved elusive. Two recent innovations have changed this. First, magnetoencephalography (MEG) mapping of motor function using the event-related beamformer (ERB) method is promising as an accurate method for localization of motor fields [1]. Second, with the advent of concurrent MEG/diffusion tensor imaging (DTI) methodologies we can now localize functional white matter pathways associated with specific motor fields and examine their integrity. We used MEG to identify motor fields for the left and right hands in young children and used these activations as seeds for tractography of the associated white matter pathways. We then calculated quantitative measures of the integrity of these tracts and evaluated whether (a) differences existed between the dominant and non-dominant hands, and (b) age-related changes were evident.

Subjects and Methods: Participants were 10 children ranging in age from 5 to 8 years (mean = 6.82 ±1.17). First, MEG data were acquired: Bi-polar EMG electrodes were placed at the left and right First Dorsal Interosseous (FDI) muscles. Subjects moved right and left index fingers separately following a visual target. Transient movements were performed once every 4 seconds (on average) for a total of 100 per side. ERB was used to localize the cortical responses known to accompany transient finger movement. Reaction times from the visual target to EMG onset with finger movement were also recorded. Second, diffusion data were acquired with a GE LX 1.5T MRI scanner using a single shot spin echo EPI DTI sequence (15 directions, b=1000, TE/TR=84.7/10,000 ms, 28 contiguous axial slices, 2.5 mm isotropic, 128 x 128 matrix, FOV = 32 cm, rbw = 125 kHz, NEX = 2).Subsequently, ERB activations were marked on the T1 anatomical scan which were non-linearly registered with the DTI sequence. Motor Field activations were then used to seed probabilistic tractography of the cortical spinal tracts on both the left and right side, with way-ward seeds through the posterior internal capsule [2]. Seed size was standardized across subjects. The resulting tracts were thresholded to eliminate non-robust probabilities by removing voxels within the lowest 10%. The subsequent left and right cortico-spinal tracts were used as regions of interest to extract mean FA. Reaction time was compared for dominant and non dominant hands, as was mean FA for the left and right cortico-spinal tracts. Finally, correlations were used to examine the relations between age and tract integrity.

Results: Reaction time for finger movement was faster for the dominant versus non-dominant hand (dominant = .36 s versus non-dominant = .40 s, p = .07). The Motor Field was consistently localized to the hand area of pre-central gyrus (area 4) with tractography delineating cortical-spinal tracts descending to the midbrain (Figure 1). Mean FA for the functionally seeded left cortico-spinal tract (dominant) was greater than the right cortical-spinal tract (left = .45, right = .40, p = .04). Furthermore, age related changes were evident for the left, but not the right cortico-spinal tract (left, r = .64, p = .05; right, r = .31, p > .10).

Fig. 1. DTI Tractography based on MEG ROI Seed Points



Conclusions: In the present study, combining MEG/DTI methods yielded novel information regarding eloquent motor cortex, associated cortico-spinal tracts, and how these may underlie developmental change in hand dominance. We found that FA for the dominant functional motor pathway, seeded from a motor field activation was greater than for the non-dominant hand in young children. This greater integrity may underlie hand dominance. That is, greater integrity in the white matter tract may facilitate faster signal conduction, yielding increased efficiency of motor control and movement. Whether this increase integrity reflects some genetic determinant or is a consequence of greater functional use of this pathway due to some other variable remains to be determined. Further, we found that age related changes were evident for the dominant functional motor pathway only, indicating that changes in the integrity of the dominant pathway occur sooner than for the non-dominant hand.

Reference:

[1] Brovelli A., et al. (2005) NeuroImage. 28:154, [2] Behrens TEJ., *et al*. (2003) MRM. 50:1077