Pre-surgical mapping using magnetoencephalography and diffusion tensor tractography reveals a case of neuroplasticity

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Introduction and Purpose: Cerebral plasticity reflects the capacity of the brain to re-organize following insult, such that unaffected tissue assumes the functions normally carried out by injured brain tissue. The ability to identify neuroplastic changes in the brain prior to surgery enables the resection of diseased neural tissue while ensuring that brain regions which have assumed new functions are avoided, and residual deficits are minimized. Such information is especially critical to optimize postsurgical outcome in children because their white matter is maturing and, hence, is vulnerable to insult. Anatomical landmarks have typically been employed to identify motor cortex for use in diffusion tensor imaging (DTI) tractography seeding of the cortico-spinal tracts (CSTs). Concerns have been raised that the use of an anatomical approach for seeding regions of interest may be insufficient because the primary motor area and CSTs may become re-organized in the presence of a cerebral space-occupying lesion and, thus, may not be present in the presumed anatomic location. Here, we use combined functional-tractography methods to delineate the CSTs of an 11-year old female who presented with an arteriovenous malformation (AVM). Concurrent magnetoencephalography (MEG) and DTI techniques were useful in revealing a case of cerebral plasticity in which motor function of the patient remained intact despite the contra-lateral displacement of her CST by the AVM.

Subject and Methods: The 11.83-year-old female presented for pre-surgical imaging evaluation of motor function following diagnosis of an AVM in the left parasagittal region with residual cystic encephalomalacia of the left parietal lobe. The patient had a history of intracranial bleeding and right-sided weakness. First, MEG data were acquired: Bi-polar EMG electrodes were placed at the left and right First Dorsal Interosseous (FDI) muscles. The subject moved her right and left index fingers separately, following a visual target. Transient movements were performed once every 4s (on average) for a total of 100 movements/side. ERB was used to localize the cortical responses known to accompany transient finger movement. Second, diffusion data were acquired with a GE LX 1.5T MRI scanner using a single shot spin echo EPI DTI sequence (15 – 25 directions, b=1000s/mm^2, TE/TR=84.7/10,000 ms, 42 contiguous axial slices, 2-3 mm isotropic, 128 x 128 matrix, FOV = 24cm, rbw = 125 kHz, NEX = 1). MEG activations marked on the T1 anatomical scan were non-linearly registered with the DTI sequence and used as seeds from which to functionally delineate the CSTs. The CSTs were also launched anatomically using the pre-central gyrus as an initial seed and the internal capsule as a wayward seed. All CSTs were used as regions of interest from which to extract measures of fractional anisotropy (FA).

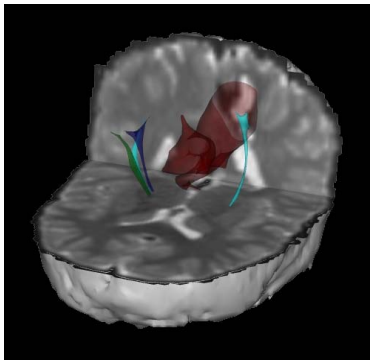

Figure 1. AVM (red), anatomical tracts (blue) and functional tracts (purple and green) depicted in a 3-D image of the patient's brain.

Results: The functional activation point and corresponding motor tract for right finger movement (green) were located on the contra-lateral side of the lesion, and were within 1 cm of the activation point and tract that were associated with left finger movement (purple). Accordingly, two discrete motor tracts (one corresponding to the affected and one to the unaffected hand) were delineated in the right hemisphere (Figure 1). A single anatomical tract was delineated in each hemisphere (blue; Figure 1). Mean FA for the anatomically-seeded tract on the affected side was substantially lower than for the anatomically-seeded tract on the unaffected side (0.45 versus 0.55). The functionally-seeded tracts had FA values of 0.52 and 0.53.

Conclusions: The reduced FA of the anatomical tract in the affected hemisphere is evidence for compromised structural integrity, perhaps due to damage from the AVM presence. Compromised structural integrity suggests a tract that is not functionally active in finger movement. Indeed, the peak of neural activity in the motor cortex generated following right finger movement was seen in the ipsilateral right hemisphere in this patient rather than in the left hemisphere. This observation of ipsilateral motor function is consistent with previous reports of cortical re-organization due to lesions of the CST (Gerloff et al., 2006) and may represent a classic case of cerebral plasticity. If the anatomical landmark had been used exclusively to delineate the CST for pre-surgical mapping, there would be no way of discerning that a functional tract may have been contra-laterally shifted as a result of plasticity. Taken together, these findings suggest that use of the MEG activation point as a seed was effective for the identification of CSTs required for finger movement. The functional seed is especially valuable in cases of plasticity such as this. Pre-operative assessment for intracranial resection requires an approach that will provide accurate information regarding the location of critical tissue. The more precise the localization of important brain tissue, the better the surgical planning and subsequent prediction of clinical outcome. These data present the functional seed as a reliable tool for launching neural tracts during pre-surgical evaluation in children. Moreover, these findings demonstrate that using a concurrent MEG and DTI approach to delineate these tracts is invaluable when evaluating plasticity in the developing brain.