Hemiplegic Cerebral Palsy: Mapping Brain Plasticity using Multimodal Neuroimaging

[1]Sameer Allahabadi, [2]Yanlong Song PhD, [3]Emily Brock MS, [4]Christos Papadelis PhD

RESEARCH QUESTION:

With the use of functional and structural neuroimaging, such as magnetoencephalography (MEG) combined with high-density electroencephalography (HD-EEG), and diffusor tensor imaging (DTI), can we map and better characterize brain plasticity changes in pediatric patients with hemiplegic cerebral palsy (HCP)? Are the delays in visuomotor tasks in children with HCP strictly due to musculoskeletal impairments or do cortical oscillations play a role?

BACKGROUND:

Cerebral Palsy (CP) is the most prevalent physical disability in early childhood in the United States. CP is deteriorating disease that affects both a child and a parent's leading to functional and motor impairments, which begin in early childhood. One of the common forms of CP, HCP affects only one side of the body, usually both upper and lower extremities. HCP is often caused by a periventricular white matter injury (PV-WMI) of the developing brain. Here, we mapped functional changes that occur at the primary motor and somatosensory cortices, as well as the white matter fibers [corticospinal motor (CST) & thalamocortical sensory tracts (TST)]. A common deficit in children with hemiplegic cerebral palsy (HCP) is abnormal upper limb motor functioning. Although musculoskeletal impairments are seen in most of these children, musculoskeletal deformations may not be the sole reason for their motor aberrations. Alterations in brain activity likely contribute to motor deficits in children with HCP.

METHODS:

A retrospective database was collected focusing on all children treated at Cook Children's Health Care System satisfying the following inclusion criteria: (i) a diagnosis of HCP due to PV-WMI identified by a neurologist and confirmed through a brain MRI; (ii) capable of staying relatively still for several minutes in order to perform functional neuroimaging studies; and exclusion criteria: (i) no history of trauma or brain operations; (ii) absence of metal implants, braces, baclofen pumps, and seizure history; and (iii) receiving occupational upper extremity treatment We delineated the brain plasticity changes that occur in HCP with TD children. We assessed both functional and structural mapping of the primary motor (M1) and somatosensory (S1) cortices using MEG and HD-EEG. Additionally, DTI was used to detect the integrity of the descending CMT and the ascending TST.

Through novel brain imaging techniques, cerebral palsy, an increasingly common neuromotor brain disease can be better characterized. In our study, we were able to further map the brain plasticity changes seen in HCP. We found that there were differing changes in the white matter tracts that were dependent on the initial brain injury and correlated them to impairments in visuomotor tasks. Patients who suffer from cerebral palsy can benefit from focused rehabilitation on cortical planning. With the further use of robotics in the future, we could help train children in simple visuomotor tasks.

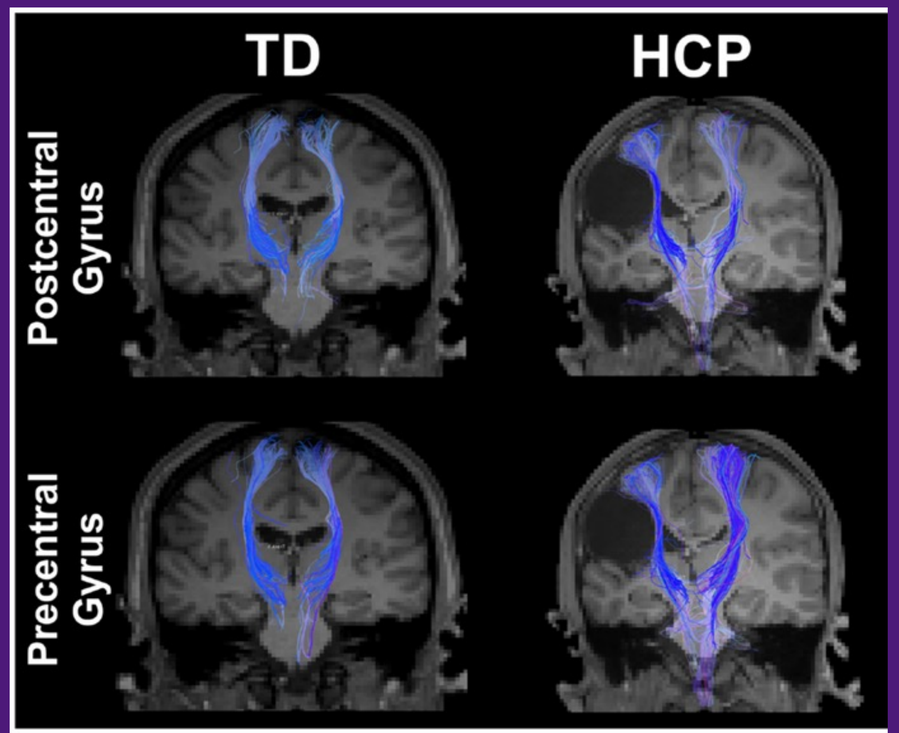

Figure 1: Thalamocortical white matter fiber tract projections in TD and HCP, patients captured via DTI and MRI imaging. Thalamocortical tract project to the primary somatosensory cortex. Adapted from 'Cortical somatosensory reorganization in children with spastic cerebral palsy: a multimodal neuroimaging study' by Papadelis et al., 2014, Frontiers in Human Neuroscience

RESULTS:

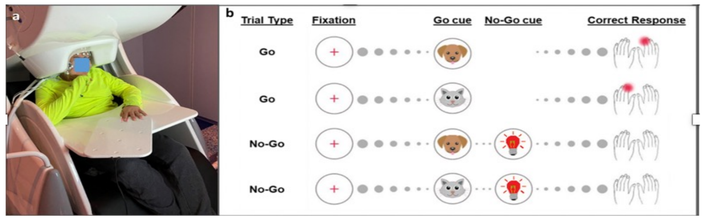

Figure 2. *Go trials were defined by when the patient saw either a cat or a dog as the image. If a dog was seen, they were instructed to tap their R index finger, if a cat was seen, their L index finger. No-go trials were defined by when the patient saw either a cat or dog plus a red light and were instructed to not tap any finger.*

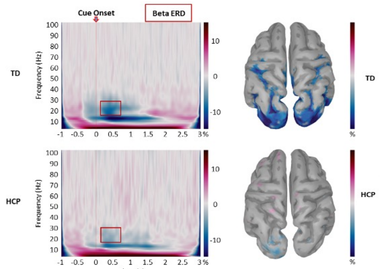

Figure 3: *Source Level beta ERD. ERD refers to event-related desynchronization or the short-lasting attenuation signal in the cortices of the brain prior to a visual stimulation. The image of the brain on the right illustrates the stronger signal in typically developing children as compared to children with HCP. The graph on the left of the image correlates with the image. Additionally, the brain image shows the localization of the signal*

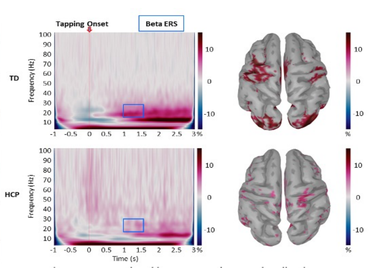

Figure 4: *Source level beta ERS and source localization. ERS refers to event-related synchronization or the power of the increase or decrease in the EEG waveform of a specific frequency during motor execution. The image of the brain on the right illustrates that there the stronger signal in typically developing children as compared to children with HCP. The graph on the left of the image correlates with the image. Additionally, the brain image shows the localization of the signal.*

FUTURE DIRECTIONS:

With the ability to measure neuronal activity and compare it to controls, we now have a measurement or capability to assess visuomotor rehabilitation methods in patients with cerebral palsy. Additionally, we have specific cortices that we can target, such as the superiorparietal and V1 and V5 visual areas. Rehabilitation methods are continually advancing and improving. Robotic rehabilitation will play a crucial role in improving patients' functional outcomes with cerebral palsy. The Amadeo Robot has shown clinical improvements in patients who have suffered from a first-time stroke, with resulting hemiparesis. Performing three hours of neuro physiotherapy, which included skill and gait training, clinical outcomes improved for all seven subjects in a study conducted by Sale et al. Despite the success of studies, there continues to be a need to perform further studies to help reduce the disease burden of cerebral palsy.

ACKNOWLEDGEMENTS:

Christos Papadelis, Ph.D., Yanlong Song Ph.D., Emily Brock MS, Cook Children's

References:

Papadelis, C., et al. (2014). "Cortical somatosensory reorganization in children with spastic cerebral palsy: a multimodal neuroimaging study." Front Hum Neurosci 8: 725.

Sale P, Lombardi V, Franceschini M. Hand robotics rehabilitation: feasibility and preliminary results of a robotic treatment in patients with hemiparesis. Stroke Res Treat. 2012; 2012:820931. doi: 10.1155/2012/820931. Epub 2012 Dec 26. PMID: 23320252; PMCID: PMC3540892.