2014 ISMRM Neuro Weekend Session: Traumatic Brain Injury

Advanced MR Imaging and Spectroscopy of Traumatic Brain Injury: What is the Potential?

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Highlights:

1. More advanced imaging techniques are required to detect the more subtle effects of mild traumatic brain injury that is not visualized in conventional brain imaging methods.
2. Technical developments specific to TBI such as hardware improvements, novel pulse sequences, and advanced post-processing methods will allow for the identification of biomarkers of brain injury.
3. Numerous questions need to be answered to better understand the complex underlying pathophysiology of brain injury.

Target Audience:

Imaging specialists and clinicians interested in the latest MR technologies for brain injury.

Outcome/Objectives:

The goal of this talk is to discuss emerging MR imaging and spectroscopy methods that are currently in development or utilized for ongoing studies in brain injury. Participants will be provided with an overview of the new technologies ranging from promising approaches that may be several years away from clinical use to novel development of existing technologies that focus on addressing the unmet needs of patients suffering from traumatic brain injury.

Purpose:

Each year between 1.6 and 3.8 million individuals in the US experience a mild traumatic brain injury (mTBI). Most who experience mTBI recover within days to weeks, although approximately 15-30% have persistent post-concussive syndrome (PCCS), the so-called "miserable minority". Furthermore, there has been rising concern regarding those individuals that experience repetitive concussions, such as sports athletes and soldiers, that at risk for developing the neurodegenerative disease, chronic traumatic encephalopathy (CTE). Diagnosis and prognosis of these conditions is difficult as cognitive and clinical symptoms are quite variable and conventional CT and MRI techniques do not reveal brain alterations. Therefore there is a strong need to develop new imaging methods that are sensitive to the underlying pathophysiological changes that occur in mTBI and potentially to diagnosis conditions such as PCCS and CTE early on to allow for treatments that can reverse the devastating long-term effects.

Methods:

While most neuroimaging hardware development has been moving towards higher field strengths with improvements in spatial and spectral resolution, the latest developments in TBI imaging have in fact gone very much in the opposite direction. For example, development of low-field MRI for use on the battlefield with hyperpolarized biomarkers of injury has been of interest to the military for TBI imaging in soldiers. While in the proof of concept stage, it is a promising new approach that would be relevant to the practical issues surrounding concussion whether on the battlefield or football field. Other hardware developments include gradient improvements that will allow for much greater b values and shorter TE for diffusion tensor imaging (DTI) studies that provide more detailed mapping of fiber tracts,

allowing for new “connectome” models of brain injury. The combination of different imaging modalities such as PET-MR may also open new windows into the underlying processes in brain injury.

Novel software improvements to existing imaging technologies to make them more sensitive to brain injury are the more immediate approaches that are being explored in ongoing research studies. Structural MR findings have shown reduced overall brain volume in chronic mTBI, reduced cortical gray matter, and decreased white matter volume. DTI can quantify subtle changes in tissue integrity that reflect microstructural axonal injuries, the most common injury in mTBI. Magnetic Resonance Spectroscopy (MRS), which measures brain chemistry sensitive to neuronal and diffuse axonal injury (DAI)as well as other pathological processes such as neuroinflammation. Other promising neuroimaging techniques include Susceptibility-Weighted Imaging (SWI), which measures micro- and contrast-enhanced MRI for detection of blood-brain barrier permeability changes hemorrhages that may occur in mTBI.

Results/ Discussion:

While all of the different technical developments show great promise, there remain a number of unanswered questions in which these methods need to be applied. The biggest challenge is the identification of imaging signatures that can parse the difference between acute brain injury, chronic effects of repetitive brain trauma, and the development of CTE. Imaging biomarkers that are specific to each of these conditions will be important for diagnosis, treatment, and hopefully prevention of progressive neurological damage. A number of factors need to be considered in the quest to identify these biomarkers. Brain injury by nature can be very heterogeneous; trauma to different parts of the brain via different mechanisms of trauma can result in different clinical presentations of brain injury. These different presentations may or may not share the same underlying pathophysiology. Genetic and environmental variations between individual patients likely also influence the imaging signatures. Furthermore, the comorbidity of different diseases such as Alzheimer’s disease, PTSD, and/or depression may obfuscate the presentation of TBI. Few studies have examined the longitudinal changes that occur in each of the different modalities nor have they determined whether or not neuroimaging biomarkers will be effective for treatment monitoring. Finally, in addition to examining the strength of multimodal imaging, the incorporation of neuroimaging results to overall metrics for brain injury including neuropsychological evaluation, blood and/or CSF biomarkers, genetic tests (such as APOE), and clinical evaluation will likely provide the most complete picture of the long term effects of TBI.

Conclusion:

While research in neuroimaging of brain injury still has many questions to answer, technological improvements in MR software and hardware methods show tremendous promise in providing non-invasive, quantitative, and objective biomarkers for TBI that will provide a platform on which treatments for this condition can be developed and evaluated.

References:

Select recent reviews of neuroimaging methods in brain injury and concussion:

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