MRI in Treatment Planning

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Multiple sclerosis (MS), a demyelinating inflammatory neurological disease, has long been considered autoimmune in nature. However, it has been known for more than 100 years that there is a venous component to MS as well. Recent evidence has shown that vascular abnormalities may play a major role in the pathogenesis of MS. These vascular abnormalities have been seen in the venous drainage system, specifically, the jugular veins in the neck and the azygos vein. The presence of reduced flow in some vessels may lead to an increase in flow resistance on the venous side causing "Cerebral Spinal Venous Insufficiency or CCSVI". These venous abnormalities have been reported in a high percentage of the MS population (1), however, duplicating this work and evaluating these landmarks using different techniques (such as Magnetic Resonance Imaging), will give more confidence to conclude whether or not the vascular component plays a key role in the pathogenesis of MS.

Thus, we developed a new MR CCSVI imaging protocol to address this issue using anatomy, flow and susceptibility weighted imaging (SWI) to measure iron content and visualize the small veins in the brain. The combined conventional and CCSVI/SWI MR imaging protocol includes the following sequences: axial 3D T1WI, 2D T2WI, sagittal 2D Fluid Attenuated Inversion Recovery (FLAIR), flow quantification sequences with v_{enc} = 50 cm/sec (upper, middle and lower neck levels), v_{enc} = 15 cm/sec for cerebrospinal fluid flow (C1/C2 level), SWI of the brain and neck, dynamic time resolved MR Venography (MRV) vertex to thoracic inlet, post-contrast axial 3D T1WI and 2D time-of-flight (TOF) for the head, neck and spine.

These data are then processed for anatomic viewing in 2D and 3D, and fully quantified for flow measurements, stenosis and FLAIR lesion load. These provide information about the major vessels, collateralization, abnormal flow patterns such as reflux, abnormal valves when possible, total cardiac input/output to and from the brain,

stenoses, the presence or absence of new lesions and abnormal iron content. For the latter, SWI phase images are used to quantify iron content. The regions of interest are MS lesions, the basal ganglia and the thalamus including the pulvinar thalamus.

Generally, we have found that there are a broad range of venous abnormalities that can be seen with MRI. We categorized the various forms of CCSVI under the general headings of truncular venous malformations (TVM), stenoses, aberrant flow pathways, septum or membranous material, abnormal valves, abnormal flow and abnormal iron content. For the anatomical characteristics we see: stenoses (in the form of conventional narrowing or pinching (pancaking) of the vessels); truncular venous malformations (at the bottom or top of the internal jugular system); long string like narrowing; multiple stenoses; internal jugular veins (IJV) fed by other veins; dilated lower IJV by the confluence; the presence of valves; a line demarcating a change in contrast in the middle, above the bulge, or at the confluence in the time resolved contrast enhanced data; early time point jetting and apparent narrowing followed by a late time point broadening of the vessel; both externals merging above the confluence and stenosis below these points; no jugular vein(s); presence of what appear to be “stuck” valves; and for the functional flow aspects include: bulging with clear circulatory flow; no flow in major veins (IJV, external jugular vein (EJV), vertebral vein (VV) or deep cervical vein (DCV)); slow flow less than 1cm/sec in the IJV; ratio of sub-dominant to dominant IJV or in general second fastest to fastest veins less than 0.25; and arterial/venous mismatch in measured flow. *All of these act as potential biomarkers of abnormal flow.*

The major problem to date demonstrating the importance of the vascular biomarkers is a lack of normal volunteers in the hundreds to complement the data from MS patients which is now in the thousands. Once sufficient statistics are made available a much clearer picture will emerge regarding which of these biomarkers or more likely which combination of these biomarkers is the most important to characterize the disease. From that perspective a combined effort internationally to create a database incorporating all imaging methods from ultrasound to MR imaging to angiography along with patient records and patient follow up will provide the most important baseline data to draw the strongest conclusions and better understand multiple sclerosis.