Diffusion Tensor Imaging and MR Spectroscopy in Patients with Hydrocephalus

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Introduction: Hydrocephalus is the accumulation of cerebral spinal fluid (CSF), from excessive production of CSF by the ventricles, a block in the circulation of the fluid, or due to brain tissue loss. Although the causes of hydrocephalus are well documented, the underlying mechanism at a cellular level is not well understood. In older patients with severe hydrocephalus, a very thin cortical mantle appears compatible with normal or superior intellectual function. One theory that may explain this paradox is that in the face of hydrocephalus, the brain becomes temporarily hypo-osmolar. Osmolytes leave the intracellular space, followed by shrinkage of brain cells, thereby restoring normal intracellular osmotic pressure but resulting in the observed reduction of brain volume due to the dilation of the ventricles. Magnetic resonance spectroscopy (MRS) can provide quantitative measurements of cerebral osmolytes such as N-acetyle aspartate (NAA), choline (Cho), creatine (Cr), and myo-inositol (mI). Diffusion tensor imaging (DTI) can also be acquired concurrently to provide measurements of fractional anisotropy (FA) that are directly correlated with extracellular space.

Methods: Proton MRS and DTI were acquired in 10 patients with hydrocephalus and 10 normal, non-hydrocephalic age-matched controls. Proton MRS was acquired using single voxel short-echo (TE=35ms) MRS in volumes of interest (8cc) located in the posterior cingulate gyrus and left parietal white matter. Quantitative measurements included a T2 seven-point assay to measure CSF and brain matter compartmentation as previously described [1]. DTI was acquired using spin-echo echo planar imaging using pulsed-gradient/Stejskal-Tanner diffusion weighting and spectral-spatial RF excitation (b-value=1000, TR=8000ms, gradient duration = 20ms, FOV=24cm, matrix=128x128, NEX=1, 17-19 slices) [2]. Four repetitions of each diffusion weighted image as well as 2 repetitions of non-diffusion weighted images were acquired and processed using specialized software. Tensorcalc (Moseley et al, Stanford University) was used to generate FA maps of the raw data. DTIstudio (Mori et al, Johns Hopkins University) was used to generate fiber tracts based on the FACT algorithm [3]. User-defined regions were chosen adjacent to the lateral edge of the ventricles and a FA threshold of 0.4 and maximum angle of curvature of 70^0 were used.

Results: MRS results demonstrated normal metabolite concentrations in hydrocephalus patients (not shown). This would appear to indicate that cerebral metabolite and osmolyte concentrations remain constant thus explaining how patients can retain normal intellectual function despite the decrease in brain volume. Fractional anisotropy demonstrates significant increases to the lateral edges of the ventricles (Figure 1). Furthermore, fiber tracking results demonstrate an increase in the density of fibers within the thinning mantle of the cortex (Figure 2).

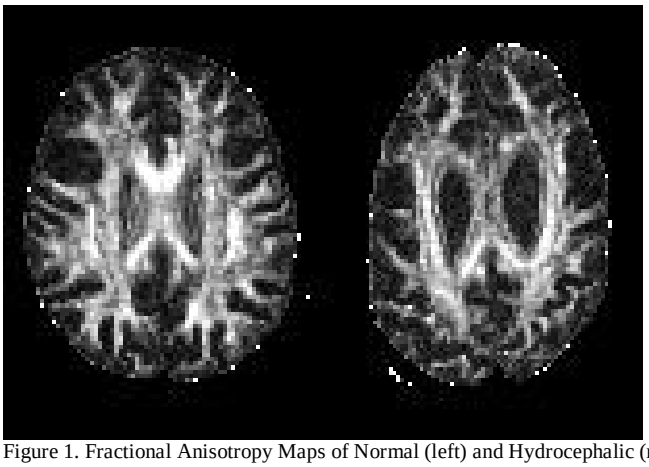

Figure 1. Fractional Anisotropy Maps of Normal (left) and Hydrocephalic (right) brain.

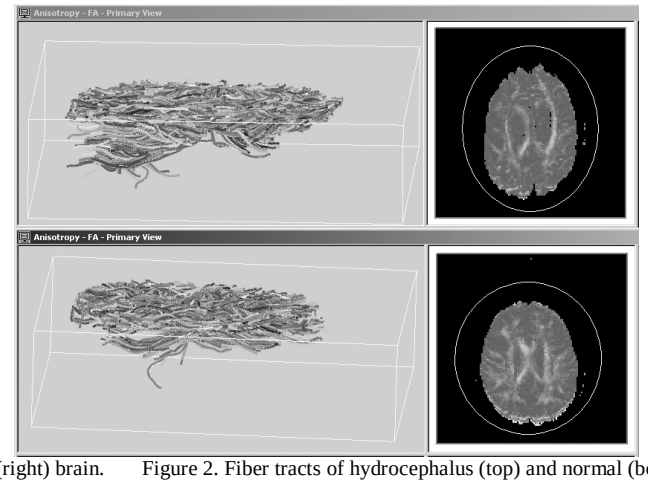

Figure 2. Fiber tracts of hydrocephalus (top) and normal (bottom).

Conclusion: The results of MRS support the argument that osmolytes are preserved with hydrocephalus, therefore the same volume of brain contains more functioning brain cells. This is further supported by the increase in FA and density of fiber tracts adjacent to the ventricles.

References:

1. Ernst et al. MRM 1997. 2. Moseley et al. Radiology 176: 439-4446. 1990. 3. Mori et al. Annals of Neurology. 45: 265-269. 1999.

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