Magnetic Resonance Elastography of Normal Pressure Hydrocephalus

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Target Audience: Physicians and scientists interested in brain MR Elastography and normal pressure hydrocephalus.

Purpose: Normal pressure hydrocephalus (NPH) is a treatable condition that presents with cognitive impairment, gait abnormality and urinary incontinence in older adults. The pathophysiology of NPH is not completely understood however shunt tube placement is an effective therapy in most cases[1]. Complications associated with shunt tube placement, the unpredictable response to the treatment and difficulty of diagnosis necessitates better characterization of surgical candidates. The investigation of novel techniques to evaluate neurologic and imaging changes in NPH patients before and after shunt placement continue [2-5]. The purpose of this study was compare brain tissue stiffness in NPH patients with age and sex matched healthy volunteers.

Methods: MR Elastrography (MRE) was performed on 11 NPH patients (age range of 67-79 years) and 21 healthy volunteers with a similar age range (67-80 years) (Fig. 1). Studies were performed on a 3T scanner with a single-shot spin-echo EPI pulse sequence (SIGNA Excite, GE Healthcare, Waukesha, WI). Shear waves were introduced into the brain through an external source of vibration with a frequency of 60 Hz using a pneumatic active driver. We applied a novel MRE post-processing technique that has been demonstrated to have a high test-retest reliability which minimizes edge-related artifacts, noise and atrophy-related biases commonly affecting brain MRE methods [6]. We calculated the elasticity of different regions of interest (ROIs) in the brain including whole brain excluding cerebellum (cerebrum), frontal, temporal, parietal, occipital lobes, deep GM/WM (insula, deep gray nuclei and white matter tracts) and the cerebellum. Brain stiffness results of the normal control group were fitted to a linear regression model to assess possible confounding factors of age and sex in the specific age range. A trend with age was found, as in previous work [7], although in this narrow age range it did not reach statistical significance (p-value 0.1). Also there was no significant linear relationship between sex and brain stiffness in our normal control group in this small age range (p-value 0.8).

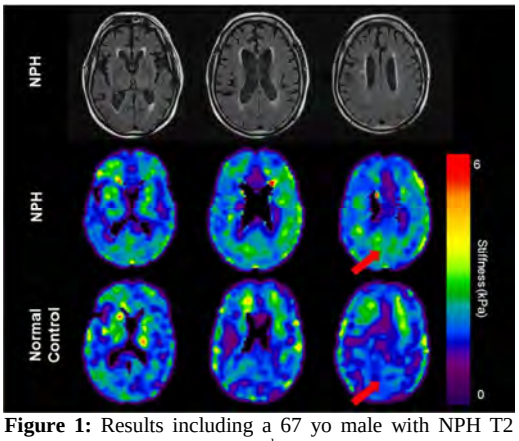

Figure 1: Results including a 67 yo male with NPH T2 FLAIR (1st row) and MRE (2nd row) compared with an age and sex matched normal control (3rd row). Findings show increased stiffness in the NPH subject compared with the normal control especially in the parietal and occipital regions (arrows).

Results: The mean median stiffness value of the cerebrum among NPH patients was 2.64 +/- 0.1 kPa, which was significantly higher than the stiffness of the cerebrum in normal controls, 2.55 +/-0.1 kPa with p-value of 0.02 (Wilcoxon rank sum test) (Fig.2). Significant increased stiffness was also noted in the occipital lobe of NPH group with p-value of 0.007 as well as the parietal lobe with p-value of 0.02 (Wilcoxon rank sum test). However, no significant difference was noted in other regions of the brain including the frontal lobe (p-value 0.29), temporal lobe (p-value 0.14), deep GM/WM (p-value 0.74) and the cerebellum (p-value 0.52).

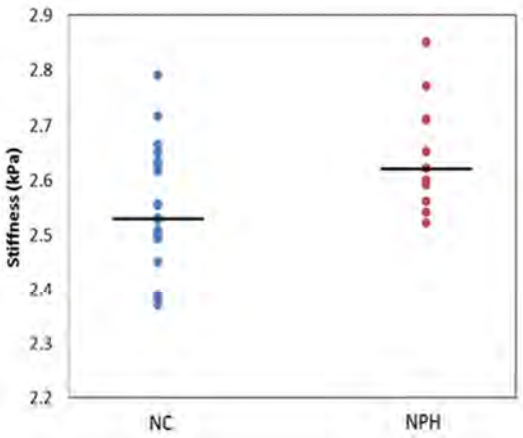

Figure 2: Summary of the Normal Control (NC) and Normal pressure hydrocephalus (NPH) cerebral stiffnesses. Lines represent the median stiffness for each group and the circles represent the cerebral median stiffness for each individual patient.

Discussion: Brain MRE demonstrated that brain stiffness is increased in patients with NPH compared with age and sex matched normal controls. A previous MRE study reported decreased brain tissue elasticity in NPH [4]. These discrepancies may result from the differences in the post-processing techniques. The current processing pipeline removes voxels with more than 50% CSF contribution, in order to reduce the effects of disproportionate distributions of CSF in lateral ventricles and sylvian fissures [12, 13], which may increase the brain surface-volume ratio in NPH and may lead to more edge-related artifacts. Applying a post-processing technique with low edge-related artifact and optimal CSF exclusion can help compensate for these changes. Impaired CSF dynamics and gradual accumulation of CSF is a suspected cause of ventriculomegaly in NPH. While several studies correlated clinical manifestations and treatment response of NPH patients with cerebral blood flow alteration [3, 8-10], recent microstructural studies have reported axonal diameter changes versus damage in corticospinal tract which could potentially be the cause of gait and urinary incontinence improvements after elimination of the local CSF pressure with shunt tube placement [11]. Brain mechanical property measurement using MRE may enable better understanding of the underlying pathophysiology in normal pressure hydrocephalus.

Conclusion: Brain MRE of patients with normal pressure hydrocephalus revealed increased brain tissue stiffness in the cerebrum, occipital and parietal lobes compared with age and sex matched normal controls.

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