Measuring Brain Stiffness In Chronically Shunted Hydrocephalus Patients Using MR Elastography

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Introduction

- Ultrasound elastography used clinically but limited because of:
  - 1) penetrate through bone (e.g. skull)
  - 2) high frequencies limit the penetration depth
- External applicators vibrate the tissue
- synchronized to the MRI sequences
- sensitized to microscopic tissue motion
- Use MRE to understand hydrocephalus
- Hypothetical changes in brain elastance with hydrocephalus related to symptoms, e.g., chronic headaches [1].
- Changes in elastance association with disease onset or in development overtime with shunting
- Causes headaches with a functioning shunt [2, 3]
- Goal: MRE use to investigate brain elastance role in pathophysiology and symptoms of pediatric hydrocephalus

Methods

- 27 short-deep hydrocephalus patients (age 14-35; median age 19), shunted as infants were selected
- 20 healthy controls (age 8-46, median age 22)
- Excluded Patients: abnormally large ventricles
- 3T Philips MRI used
- MRE data acquired, inducing vibration via MRI compatible pneumatic pistons at 30Hz, transmitted through the zygomatic arches
- Clinical measures: The Headache Disability Inventory (HDI), Hydrocephalus Outcome Questionnaire (HOQ), and other clinical data collected e.g., Beck Depression Inventory (BDI), clinical history and outcome, and shunt revision
- Brain elastance averaged across white and grey matter masks and within lobar regions
- Investigate linear associations with ventricular size, HDI and HOQ

Results

- Brain stiffness was reduced in patients compared to controls
- Whole brain WM: G* = 1.71 ± 0.20 kPa vs. 1.93 ± 0.13 kPa, p < 0.001
- Frontal GM: G* = 1.48 ± 0.14 kPa vs. 1.34 ± 0.16 kPa, p = 0.001
- Occipital GM: G* = 1.28 ± 0.11 kPa vs. 1.11 ± 0.20 kPa, p = 0.001
- Parietal: G* = 1.30 ± 0.14 kPa vs. 1.23 ± 0.21 kPa, p = 0.039

Conclusion & References

- Brain elastance is lower (softer) in chronically shunted hydrocephalus
- Enlarged ventricles, as indexed by linear measures of ventricle size, are associated with softer grey and white matter
- Softer brain tissue is associated with history of multiple shunt revisions

References:


Figure 1: MRE vibrations are induced through spring loaded, air activated pistons at 30Hz, transmitted through the zygomatic arches.

Figure 2: Whole brain white matter stiffness

Objective 1A: Patient and control brain stiffness

Whole brain white matter stiffness

Graph of Brain Stiffness in Patients and Control Group. Brain stiffness is decreased in white matter in chronically shunted patients compared to healthy controls. WM: G* = 1.71 ± 0.20 kPa vs. 1.93 ± 0.13 kPa respectively.

Objective 1B: Regional differences in brain stiffness

Lobar grey matter stiffness

Objective 2A: Ventricular Size and Headache Disability Inventory Association with Brain Stiffness

Figure 3: Brain Regional Stiffness Differences Between Patients and Control Group. Stiffness is reduced in patients compared to controls.

Objective 2B: Shunt revision number association to brain stiffness

Figure 4: Brain Regional Stiffness Correlations to Ventricular size and Headache Disability Inventory Score HDI

Figure 5: Whole Matter and Occipital Grey Matter Stiffness of Control and Patient’s Group with Different Numbers of Shunt Revisions

Figure 6: Occipital Grey Matter stiffness in the patients group with more than one revision had decreased stiffness compared to the controls and patients with less than one shunt revision.