Brain Volume and CSF Disorders: A Three Dimensional Analysis

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Abstract

Hydrocephalus and related cerebral spinal fluid (CSF) disorders remain a mystery, with no known cure, only treatment options. 1 in 500 children are affected and ventricular shunt procedures, the treatment for these disorders, account for the second highest readmission prevalence to hospitals of those with CSF disorders. Using 3D modeling constructions from MRI's, we will quantitatively explore how the disease course of the brain is changed by current surgical interventions in patients with CSF disorders, particularly hydrocephalus, Chiari malformation, and tethered cord. We are especially interested in how volumetric and directional changes of the brain's ventricles, cranial blood vessels, and matter distribution are correlated with patient neurological performance. CSF disorders are not standalone illnesses, but rather part of a more complex disease process of the brain and we hope to provide insight into this process to understand the dynamic effects of treatment options and to create a framework leading to the cure.

Introduction

- Cerebral Spinal Fluid (CSF) disorders have no known cures, only treatment options
- Hydrocephalus is disturbance of formation, flow, or absorption of CSF leading to accumulation in the central nervous system (CNS) and connecting it to other CSF disorders[1]
- Hydrocephalus affects 1 in every 500 children[2]
- Ventricular shunt procedure diagnosis associated with 2nd highest hospital readmission rate in 2013[3]

Project Goals and Hypotheses

Aim: Analyze cranial volumetric changes associated with CSF disorders and their treatments.

Hypotheses:
(1) CSF changes correlate significantly with changes in brain matter and vessels
(2) Treatments for different CSF disorders cause similar unique cerebral volumetric changes

Methods and Results

Volunteers with
1) Normal Pressure Hydrocephalus
2) Chiari Malformation
3) Tethered Cord Syndrome

Exclusion: pacemaker, allergies to contrast

MRI
1) Before surgery
2) 7-14 days after surgery
3) 3 months after surgery
4) 1 year after surgery

Image Analysis

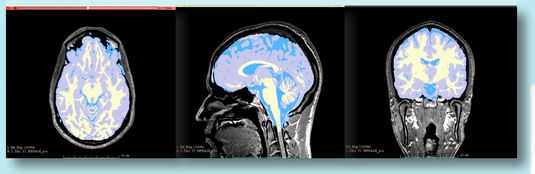
3D Slicer
a) Brain Segmentation
b) Volume Rendering

GE Advantage Workstation
a) Brain Segmentation
b) Volume Rendering

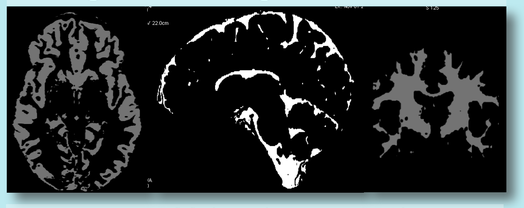
I. Brain Matter and CSF

(1) Patient T1 MRI Scans

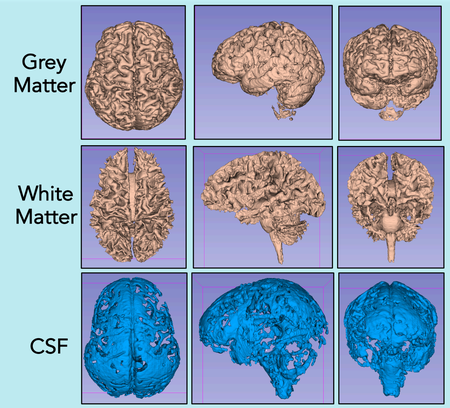
(2) Creation of EM-Map using brain atlas (3D Slicer)



(3) Thresholding by brightness and refining (GE Advantage Workstation)

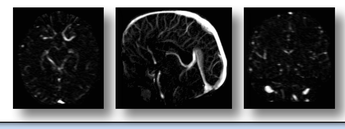


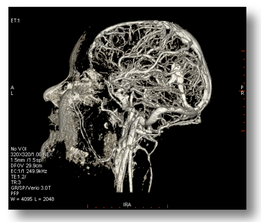
(4) Creation of fiducial map (3D Slicer)
(5) Volume rendering and analysis (3D Slicer)

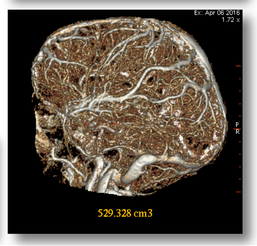


II. Blood Vessels

(1) Patient MRV Scans
(2) Remove skull and extra-cranial tissue (GE Advantage Workstation
(3) Threshold vessel material and refine structures
(4) Volumetric Analysis







Discussion and Conclusions

- 3D Slicer and GE Advantage Workstation combination allowed full brain segmentation and volume rendering and analysis
- 3D Slicer is not a clinical software but was able to yield results within 5cm^3 from GE Advantage Workstation
- Method does not work for patients under 8 years of age suggesting need for a pediatric brain atlas

Future Directions

- Development of directional change analysis algorithm in MATLAB
- Apply pediatric brain atlas
- Apply neurologic exam (Rankin Scale)
- Begin data collection process

References

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2. Flannery, M. and L. Mitchell. "Pediatric Hydrocephalus: Systematic Literature Review and Evidence-Based Guidelines. Part 1: Introduction and Methodology." *Journal of Neurosurgery Pediatrics*, 14 (2014): 3-7.
3. Berry, J.G., Toomey, S.L., Zaslavsky, A.M., Jha, A.K., Nakamura, M.M., Klein, D.J., Feng, J.Y., Shulman, S., Chiang, V.W., Kaplan, W., Hall, M., and Schuster, M.A. "Pediatric Readmission Prevalence and Variability Across Hospitals." *The Journal of the American Medical Association,* 309 (2013): 372–380.

Acknowledgments

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