Brain Volume and CSF Disorders: A Three-Dimensional Analysis

[1]Jun Kit He, AB, [2]Scott Collins, RT(R)(CT) and [2,3]Petra Klinge

[1]The Warren Alpert Medical School of Brown University
[2]Lifespan, Providence, RI
[3]Neurosurgery Foundation, Inc., Providence, RI

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Introduction

In the United States, 1 in 500 children is affected by cerebral spinal fluid (CSF) disorders, yet little is known about hydrocephalus and related CSF disorders. The treatment options available remain non-curative, and ventricular shunt procedures, which are commonly used to treat these disorders, account for the second highest readmission rate for patients with CSF disorders. More specifically, shunts impact volumetric and directional changes of the brain's ventricles, cranial blood vessels, and matter distribution; and are all correlated with patient neurological performance. The aim of this study is to use 3D modeling constructions from MRI scans to quantitatively explore how the disease course of the brain is changed by surgical interventions in patients with hydrocephalus, Chiari malformation, and tethered cord. For a volumetric analysis to be possible, a protocol was developed utilizing multiple imaging programs to create the 3D models from the 2D MRI images. This project provides insight into complex disease processes of CSF disorders and the dynamic effects of surgical intervention treatment.

Methods

Brain MRI scans will be taken of participants with normal pressure hydrocephalus, Chiari Malformation, and Tethered Cord Syndrome. Exclusion criteria include having a pacemaker and allergies to contrast. MRI scans will be taken at 4 time points: before surgery; 7-14 days after surgery; 3 months after surgery; and 1 year after surgery. The programs used for image analysis are 3D

Slicer and *GE Advantage Workstation*. Both will be used for brain segmentation and volume rendering. To analyze the grey matter, white matter, and CSF, an EM Map is created using a brain atlas. Cranial vasculature is isolated using intensity thresholds before volume rendering and volumetric analysis. Volume states are correlated to the participant's neurologic function assessed by the Modified Rankin Scale. A One-Way ANOVA is used to compare volumetric differences.

In order to create the 3D models for analysis, the tools in the programs *3D Slicer* and *GE Advantage Workstation* were found to be most helpful. For isolating grey matter, white matter, and CSF, MRI images were treated as brain slices. For each volunteer, the “slices” were kept in anatomical sequence. The “tissue” outside of the virtual image of the brain was first removed from the images. The individual types of brain matter and CSF were then separated based on thresholds of brightness in the MRI images. Finally, the brain “slices” were merged using mathematical interpolation techniques to create a smooth volume. Cranial blood vessel models were created similarly, except the MRI scans were conducted after contrast was administered to give the vessels a different brightness on image from the rest of the brain matter. The numerical volume of each of these matters was found by correlating the density of image voxels with anatomical values.

Results

Results confirm that 3D virtual models of the brain can be created for analysis by treating MRI images as brain slices. The full brain structure can be recreated by stacking these slices and using interpolation techniques. Volumetric analysis is possible by correlating voxel density with anatomical volumes. This project can now proceed to the next phase utilizing this newly developed protocol to analyze MRI scans of participants and correlate the volumetric analysis to the patients' clinical performances. Beginning in February of 2017, the MRI studies began to be collected, and further data collection and analysis should be completed by June of 2018.

Conclusion

This study has demonstrated the possibility of 3D volumetric analysis of the brain. This will be a valuable clinical tool for clinicians to have a better understanding of anatomical changes in the brain. Specifically, using this analysis technique, significant volumetric changes in brain matter and fluid are expected to be observed when analyzing the effects of ventricular shunt procedures in patients with CSF disorders.