An Automatic Surface-based Ventricular Morphometry Pipeline and Its Application in Alzheimer's Disease Research

Wen Zhang[1,5], Jie Shi[1,5], Kewei Chen[2,5], Leslie C. Baxter[3,5], Eric M. Reiman[2,5], Richard J. Caselli[4,5], Yalin Wang[1,5]

[1]School of Computing, Informatics, and Decision Systems Engineering, Arizona State University, Tempe, AZ, USA. [2]Banner Alzheimer's Institute and Banner Good Samaritan PET Center, Phoenix, AZ, USA. [3]Human Brain Imaging Laboratory, Barrow Neurological Institute, Phoenix, AZ, USA. [4]Department of Neurology, Mayo Clinic Arizona, Scottsdale, AZ, USA . [5]Arizona Alzheimer's Consortium, Phoenix, AZ, USA

wzhan139@asu.edu

Introduction

Ventricular changes are associated with a variety of human diseases such as HIV/AIDS, hydrocephalus, vascular dementia, diabetes mellitus, drug addiction, and Alzheimer's disease (AD). Currently available automated ventricular segmentation programs have been of limited use for surface-based ventricular morphometry. In this study, we present a novel automated atlas-based ventricular segmentation algorithm that reduces both the computational time and expertise required for manual segmentation. The combined holomorphic 1-form based surface analysis and this newly introduced procedure constitutes a complete automated ventricular morphometry system for structural MRI analysis. In the current research, we set out to apply our software to Alzheimer's disease imaging research

Methods

1. The T1-weighted MR images of all the subjects were first linearly registered to MNI space using FSL/FLIRT.
2. Voxel-based morphometry processing (VBM) in SPM8 toolbox was used to automatically segment each aligned T1 image to three tissue classes (GM, WM and CSF).
3. After warping the CSF probabilistic mask to the binary mask, we applied the geodesic shooting (GS) to merge all CSF masks to create a group averaged atlas in which the nonlinear deformation for each CSF mask was estimated.
4. The ALVIN (Automatic Lateral Ventricle delIneatioN) ventricle binary mask were applied to exclude CSF that is outside the lateral ventricles.
5. Warping back the group average ventricular atlas by referring the nonlinear deformation estimated in the GS registration.
6. Using a topology-preserving level set method to build a surface mesh from the binary ventricular mask.
7. The conformal grids of each ventricular surface were generated and further segment the ventricle into three parts based on its zero point on the surface.
8. After surface registration on each part, we merged them together for the extraction of surface features such as mutivariate tensor-based morphometry (mTBM) and radial distance at each surface point.

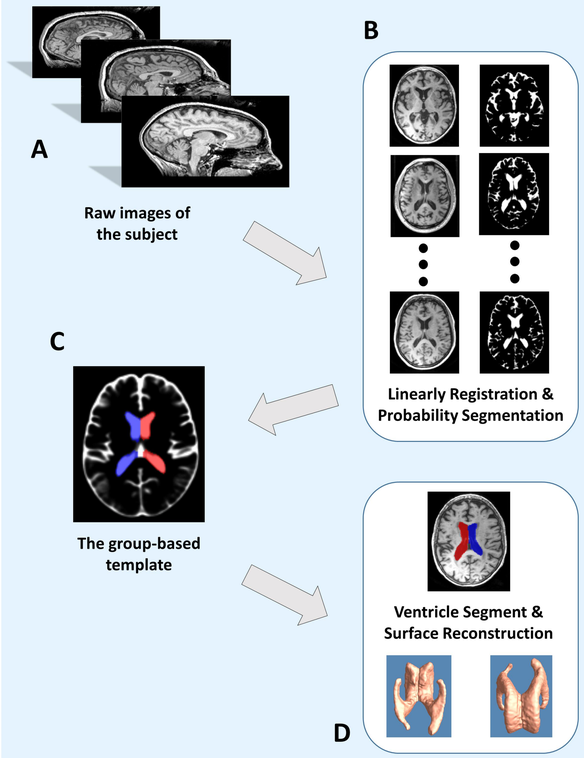

Figure 1. Illustration of the ventricle segmentation pipeline. The raw data of each subject (A) were linearly registered to the standard MNI template and then segmented to different types of tissues based on voxel probabilities using VBM toolbox (B). After that, GS registration and ALVIN binary mask were applied to create the group-wise ventricular template (C). At last, inverse the template in step (C) to individual space to obtain the ventricular volume images for every subject and the surface mesh were able to reconstructed.

Experiments

149 normal subjects from Arizona APOE cohort were included in this study including 70 e4 non-carriers (e3/e3), 46 APOE e4 heterozygotes (e3/e4) and 33 APOE e4 homozygotes (e4/e4). The results of atlas-based segmentation of lateral ventricle showed consistency and stability among all the subjects that anatomical characteristics were clearly depicted on three ventricular horns.

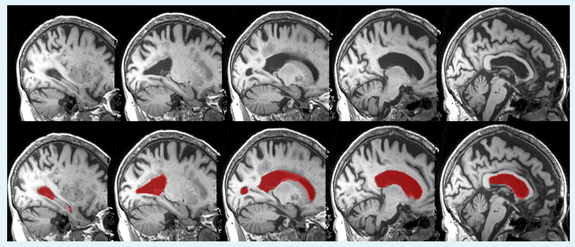

Figure 2. One sample of the segment result (left ventricle). The first line shows slices of the original images. The red color in the second line indicates the segmented ventricular volume mask.

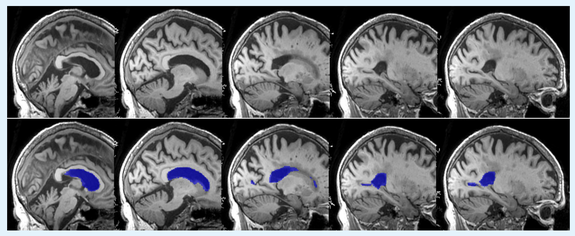

Figure 3. One sample of the segment result (right ventricle). The blue color in the second line indicates the segmented ventricular volume mask.

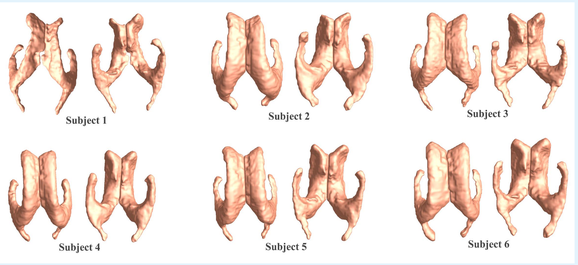

Figure 4. Six samples of the reconstructed ventricular surface meshes.

Our ongoing work is applying the obtained multivariate statistics as geometry features to study the genetic influence of APOE e4 on ventricular surfaces.

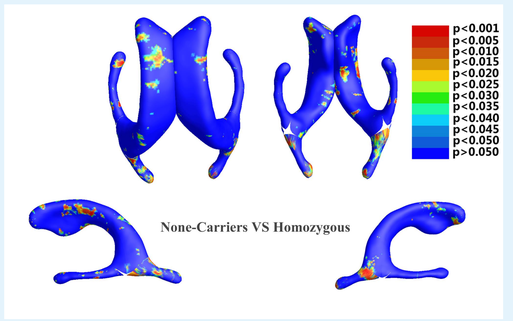

Figure 5. Statistical Result of the genetic influence of APOE E4 on ventricular surface (MADMTBM). Only Non-carriers vs Homoygous shows statistical significant with P<0.05 after permutation test.

Discussion

In this study, by combining a new atlas-based segmentation algorithm with our prior surface-based holomorphic 1-forms work, we develop an automatic surface-based ventricular morphometry pipeline. When applying to a large normal database, it worked efficiently and precisely on construction of the lateral ventricular surface. Our work may provide a convenient tool to study the genetic influence of APOE e4 in a preclinical population.

References

1. Shi, J. et al, 2013. Surface Fluid Registration of Conformal Representation: Application to Detect Disease Burden and Genetic Influence on Hippocampus. NeuroImage, 78:111-134.
2. Wang, Y. et al, 2011. Surface-based TBM Boosts Power to Detect Disease Effects on the Brain: An N=804 ADNI Study. NeuroImage, 56(4):1993-2010.
3. Kempton, Matthew J., et al. A comprehensive testing protocol for MRI neuroanatomical segmentation techniques: Evaluation of a novel lateral ventricle segmentation method. Neuroimage 58.4 (2011): 1051-1059.