Quantification of Brain Motion in Chiari Patients

Amirreza Hashemi[1,2,4], Alexander Buck[3], Malena Español[4], Bryn Martin[1,2]

[1]Conquer Chiari Research Center, University of Akron, OH, [2]Department of Mechanical Engineering, University of Akron, OH, [3]Oberarzt Institut und Poliklinik für Radiologische Diagnostik Uniklinik, Köln, Germany, [4]Department of Applied Mathematics, University of Akron, OH

Importance for Chiari Patients

Occipital headache pain in Chiari I malformation (CMI) patients is a commonly reported symptom. In this project we will develop a novel non-invasive MRI based tool to assess 3D motion of the brain stem and cerebellar tonsils and determine how motion may correlate with headache. The findings will help our fundamental understanding of CMI symptomatology and CSF system dynamics.

Abstract

A tool to assess 3D motion of the brain stem and tonsils based on MRI measurements is under development. This tool utilizes 3D structural MRI measurements obtained over the cardiac cycle. A 2D level-set edge detection algorithm was employed for reconstruction of the neural tissue edges for each time-step of the cardiac cycle in 3D. Initial results show promise to map the tissue surface motion over time and strain field.

Methods

Our approach is to develop a tool to assess brain motion utilizing techniques applied for cardiac motion quantification. A prototype semi-automated algorithm has been developed to detect a) surface motion (Figure 1) and b) strain field (Figure 2) of the neural tissue. The algorithm has been tested on a single CMI patient.

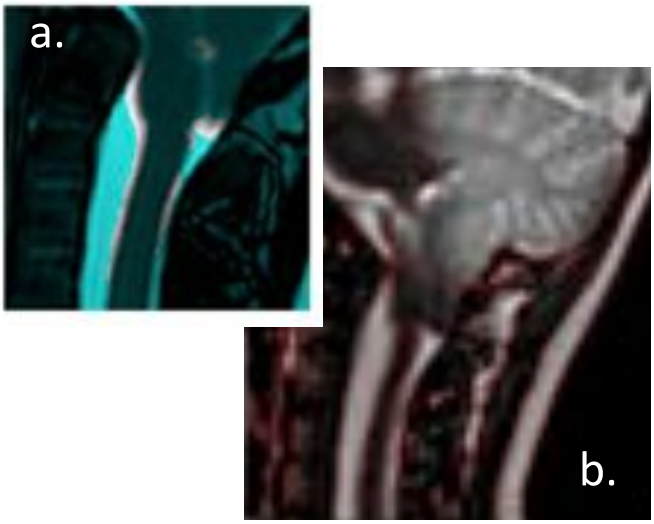

Figure 1. a) MRI image rendering of overall motion of the brain stem for a CMI patient (white region represents area of brain motion). b) Edge detection of the craniocervical junction using the preliminary 2D level-set algorithm.

Results and Discussion

The motion detection tool prototype enables selection of a critical area and extraction of the data (Figure 2). Quantification of the relative motion and velocity for a particular line of interest has been completed. A fully automated 2D edge detection algorithm was employed and successfully found the edges of the brain for the 3D volume set.

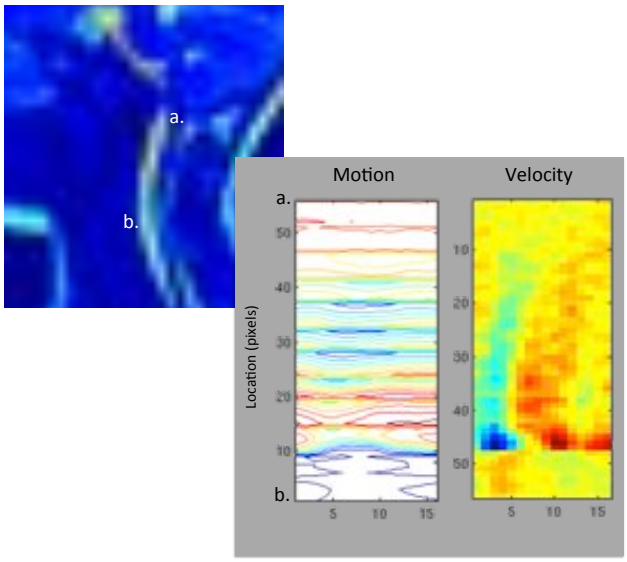

Figure 2. . Tool to detect motion of the brain over the cardiac cycle for a specific line within the region of interest (upper left).

Limitations

The algorithm for edge detection was not robust to delineate areas of the brain without motion (Figure 1). Our plan is to implement a semi-automated technique where the user specifies the boundaries of the edge detection algorithm as an initial input. The preliminary motion detection technique did not provide quantitative values for motion detection or strain field. These parameters will be added to the tool.

Future Work

Future work will enable quantification of strain field and 3D motion of the brain and validate the algorithm by in vitro and in vivo testing. The algorithm will be tested on 40 CMI patients pre and post surgery and 10 healthy controls. Overall the results will help understand the relation, if any, between brain motion and CMI severity. If successful, we expect the tool to provide important information to help neurosurgeons assess CMI.

References

1. Yiallourou TI, Kroger JR, Stergiopulos N, Maintz D, Martin BA, et al. (2012) Comparison of 4D Phase-Contrast MRI Flow Measurements to Computational Fluid Dynamics Simulations of Cerebrospinal Fluid Motion in the Cervical Spine. PLoS One 7: e52284.
2. Ono A, Suetsuna F, Ueyama K, Yokoyama T, Aburakawa S, et al. (2007) Cervical spinal motion before and after surgery in patients with Chiari malformation type I associated with syringomyelia. J Neurosurg Spine 7: 473-477.