Cardiac pulsation in retrospectively gated whole brain high-resolution T2-weighted Turbo-spin echo MRI

Yiling Shi, Bingbing Zhao, Xiaopeng Zong,
School of Biomedical Engineering, ShanghaiTech University, Shanghai, China

INTRODUCTION

Cardiac pulsation is a key driver of the cerebral spinal fluid flow. MRI signatures of cardiac pulsation may provide new insight into the alterations of the glymphatic flow in neurological disorders. Diffusion weighted imaging methods based on echo planar imaging (EPI) readout have been developed to sensitize the MRI signal to glymphatic flow. However, EPI sequence lacks sufficient spatial resolution to resolve small key structures in the glymphatic system such as the perivascular spaces and cerebral aqueduct. Furthermore, the To achieve In this study, we characterized MRI signal pulsations in whole brain T_2-weighted structural MRI sequence in healthy subjects. Cardiac synchronization was achieved through retrospective gating. Flow phantom experiments were performed to investigate the physical mechanisms of the signal pulsation.

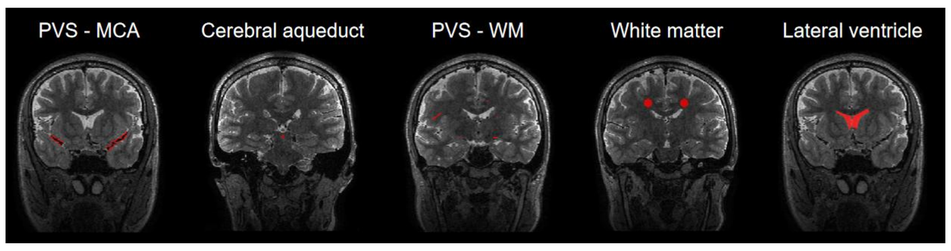
METHODS

In vivo study

Subjects Eight (aged 22-47 years, six males) healthy subjects were enrolled in this study after obtaining informed consents.

Image acquisition The 3D variable flip angle TSE sequence was performed using the following parameters: TR/TE = 3000/401 ms; resolution = 0.8×0.8×0.8 mm3; number of averages (NA) 7; acceleration factor 3; scan time 19:00 min. Cardiac pulse signal was acquired during the scan using an oximeter attached to the subject's finger. Two experimental sessions were performed for each subject to test the reproducibility of the pulsation curves and the pulsatility index.

Image analysis In vivo k-space data were separated into six cardiac phases according to their acquisition times. The image at each cardiac phase was reconstructed using the ESPIRiT algorithm [4]. Five regions of interest were manually drawn on the middle cerebral artery (MCA), cerebral aqueduct (CA), white matter (WM), and lateral ventricle (LV). The PVS was automatically segmented using a convolutional neural network model [5]. Pulsatility index was calculated from the dynamic curves as the difference between the maximum and minimum intensities divided by the mean intensity.

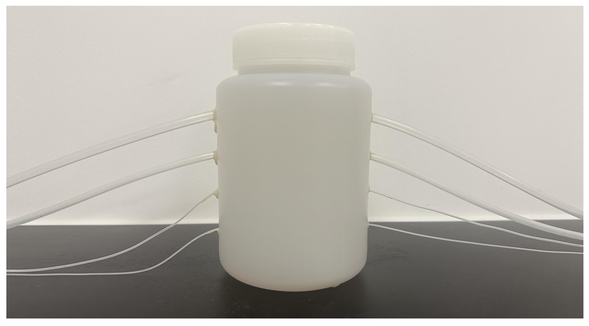


Phantom study

Phantom construction: The flow phantom consisted of two silicone tubes with inner/outer diameters of 0.5/1 mm and 3/4 mm penetrating horizontally the side walls of a cylindrical bottle through the central axis. The bottle was filled with 1.1% agarose gel and had diameter/height of 8.5/11.0 cm. Tap water flowed through the tubes with 4-5 different velocities between 0 – 16 cm/s during MRI scanning. The flow rate was controlled using a syringe pump.

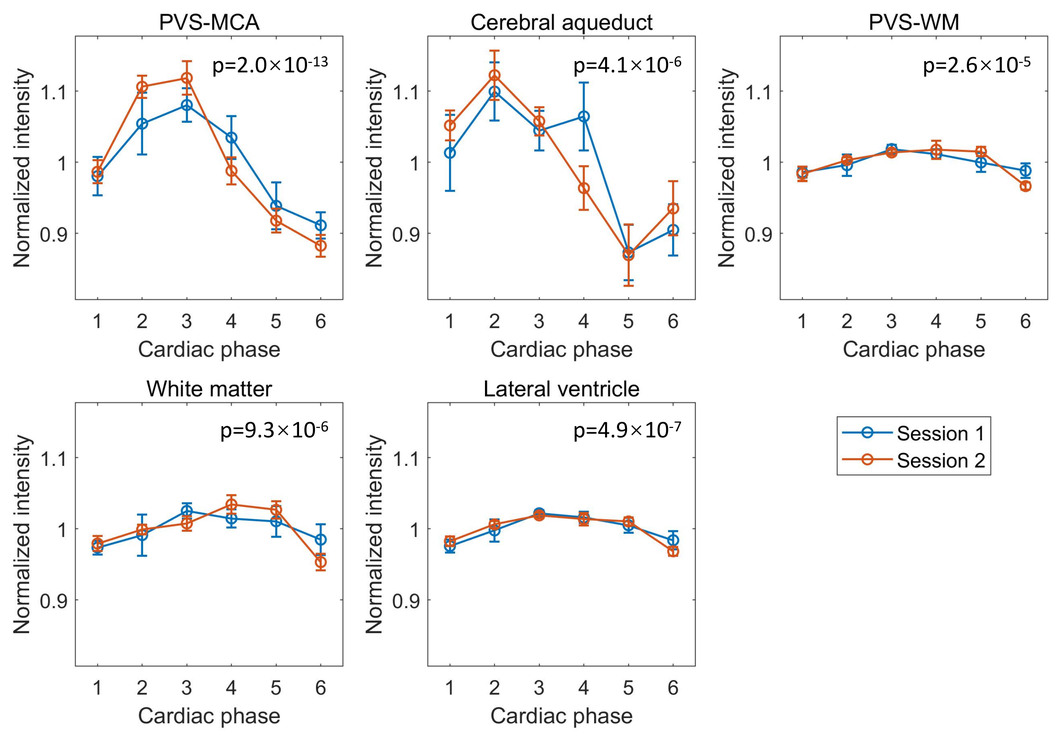
Image acquisition: The phantom images were acquired using the same protocol except for NA = 1. To study the orientation dependence of the flow signal, the scan was repeated twice with the flow perpendicular and parallel to the readout direction, respectively.

Image analysis: ROIs consisting of voxels covering the space inside the silicone tubes were manually drawn on the phantom images. Mean signal intensity within each ROIs was normalized by the mean agarose signal in a 0.8×0.8×0.8 cm3 region near the tubes to eliminate effects caused by gain changes.

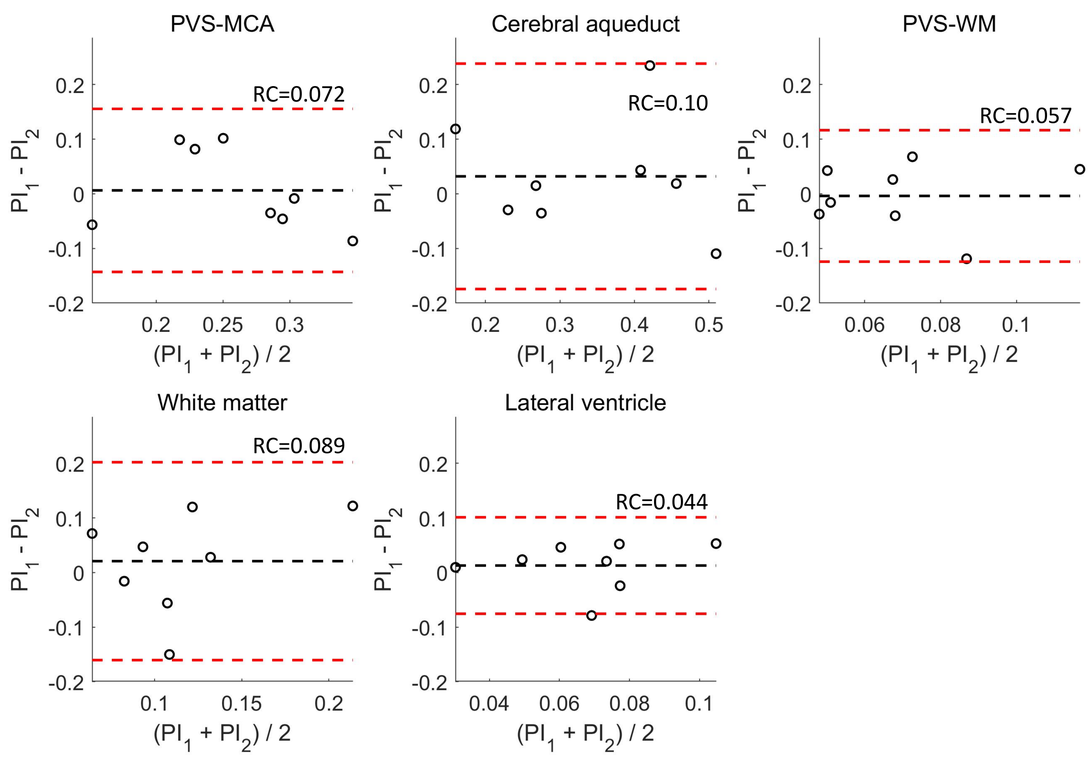


RESULTS

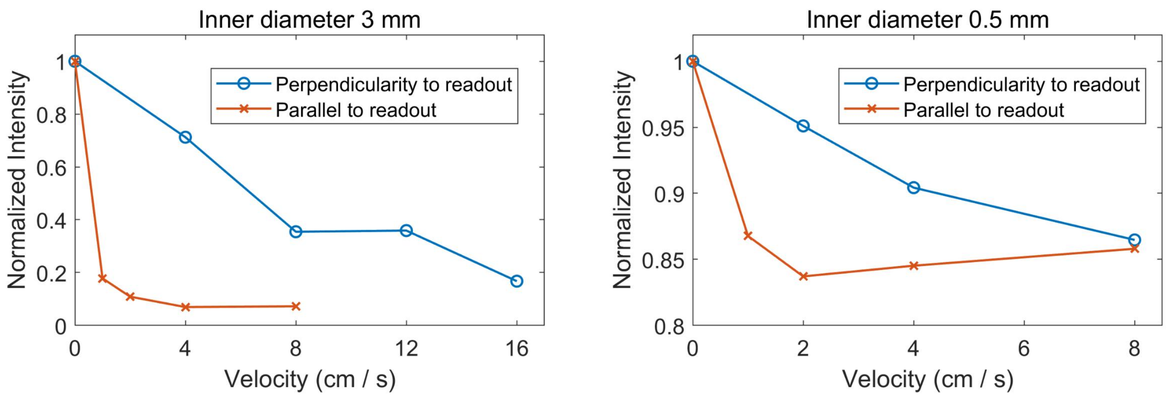
Significant signal variations ($p<2.6\times10^{-5}$) were observed across all ROIs. The signal is lowest during the systolic phase which roughly corresponds to the first and last data points. Some variations were observed between the dynamic curves between the two experimental sessions. The pulsation amplitude is higher in MCA and cerebral aqueduct than in the PVS, WM, and LV.



The Bland-Altman plots illustrate the agreement between two measurements of Pulsatility Index (PI), with a reproducibility coefficient (RC) range of 0.044 to 0.10.



In the flow phantoms, signal intensity decreased with increasing velocity and the reduction factor is larger when the flow is parallel to the readout direction.



DISCUSSION

The decreased signal intensities during the systolic phase in PVS-MCA, PVS-WM, and WM can be attributed to dilation of the enclosed penetrating arteries which reduces the volume of the PVS in those regions. On the other hand, the reduction of signals in the lateral ventricle and cerebral aqueduct may reflect the flow velocity pulsation.

CONCLUSIONS

The cardiac pulsation can be observed in different brain structures in conventional high resolution structural T2-weighted MRI images. It may serve as a new tool for measuring the driving force underlying the glymphatic system.