CARDIAC ARTIFACTS AROUND THE BRAINSTEM IN FMRI STUDIES

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Purpose

Activation in a number of deep brain structures has been reported in fMRI studies. Although many important structures exist around the brainstem, functional signal detection in these structures is more difficult than in other brain areas. Cardiac-related pulsations in and around the brainstem are likely the major contributor to this difficulty. Blood flow, cerebrospinal fluid (CSF) flow, and the physical motion of the brainstem are all possible sources of cardiac artifacts. Previous studies with MRI investigated the motion of the brainstem and the CSF flow [for example 1, 2], but it is still unclear how they affect the Echo Planar Imaging (EPI) data. The purpose of this study was to evaluate how these cardiac artifacts affect EPI data.

Methods

MR imaging: MPRAGE (T1W) and EPI images were acquired from two healthy volunteers using an Agilent 4 Tesla whole-body MRI system (Agilent Technologies) with volume coil excitation and sixteen-channel phased-array reception (Nova medical). The scan parameters for T1W and EPI are as follows. T1W: TI=0.5s, TR/TE=12.2/4.2ms, 8 shots, matrix size=128x128, 54 volumes for slice orientation perpendicular to the cerebral aqueduct and 44 volumes for slice orientation parallel to the brainstem; EPI: TR/TE=112/25ms, 4 shots, matrix size=64x64, 1000 volumes. Each session included two T1W and two EPI scans, each containing three slices oriented perpendicular to the cerebral aqueduct and four oriented parallel to the brainstem (FOV=160x160mm, slice thickness=5mm). The subject's heartbeat and respiration during scan were monitored with a pulse oximeter and a pressure sensor placed on the abdominal region. Data analysis: The relative position of a shot within a cardiac cycle was determined by comparing the shot acquisition time and the peak time of the heartbeat signal. All shots were reordered based on the cardiac cycle timing, and a one-cycle MRI time series was reconstructed. An FFT analysis was then conducted, which revealed signal components synchronized to cardiac pulses.

Results

T1W data showed that the signal synchronized to the heartbeat was localized in blood vessels around the brainstem and the optic nerve, but not in the brainstem itself or the cerebral aqueduct (Fig.1, left). In contrast, widely distributed artifacts were found in EPI images. A prominent cardiac artifact was found around the brainstem and cerebral aqueduct in the slice perpendicular to the cerebral aqueduct (Fig.1, right). For slices parallel to the brainstem, MRI signal synchronized to the heartbeat was found mainly in the lateral ventricle, the third ventricle, the cerebral aqueduct, as well as the brainstem.

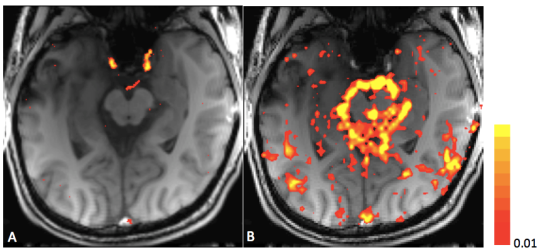

Fig 1. The artifact synchronized with cardiac pulses (A. T1W; B. EPI). The hot colors indicate the voxels whose time courses were significantly contaminated by cardiac signal (p<0.01).

Discussion

The results from T1W data suggest that physically the brainstem actually does not move as much as being feared. Since the T1W images have higher resolution and clear contrasts at the edge (boarder) of the structures, we should see some cardiac signal effects there if the structures are physically moving. Even smaller scale motion than the voxel size (1.25 x 1.25 x 5 mm) should also modulate the signal but we didn't see any cardiac modulation. It implies that the artifact caused by rigid motion at the resolution (2.5 x 2.5 x 5 mm) for EPI images is negligible. On the other hand, our data showed that EPI images suffered much broader cardiac artifacts. Taken together, these results suggest that cardiac artifacts around the brainstem in fMRI studies are not due to the physical motion in and around the brainstem, but are mainly caused by other sources, such as CSF flow and the pulsation of blood vessels. In conclusion, a significant improvement in data quality around the brainstem is expected if the methods, such as the retrospective cardiac signal fluctuation removal algorithm [3], are applied in fMRI studies exploring functional roles of the brainstem.

Reference

1. Zhong X et al., Med Phys 2009; 36(8): 3413-3419, 2. Yamada S et al., Radiology 2008; 249(2): 644-652, 3. Hu X et al., MRM 1995; 34: 201-212