Quantification of Brain Motion Using Complementary Displacement Encoding

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Introduction

Several diseases of the central nervous system, such as hydrocephalus, multiple sclerosis or Alzheimer's disease are, among others, associated with abnormal cerebrospinal fluid (CSF) dynamics in the brain. CSF pulsation is mediated by brain motion which in turn is caused by pulsation of blood in the cerebral arteries [1, 2].

In order to explore brain motion, several studies using MR velocity measurements have been presented [3]. Tissue tagging techniques have also been employed to directly measure brain tissue displacement. The CSPAMM method [4] has previously been used in conjunction with the HARP algorithm [5]. It, however, suffers from limited spatial resolution as displacement data are extracted using a narrow bandpass filter around the tagging harmonics [5]. Accordingly, only limited information of local displacement may be obtained. It is the objective of the current work to present a highly motion sensitive method with sufficient spatial resolution for brain motion quantification based on complementary displacement encoding with stimulated echoes (C-DENSE).

Methods

C-DENSE [6] was implemented by adding additional motion decoding gradients to a gated, multi-phase CSPAMM sequence. The motion encoding/decoding gradients were applied in measurement direction. The measurement direction was rotated in consecutive experiments to encode motion along all three spatial axes. The encoding sensitivity was chosen depending on the anatomical area ranging from 0.5 mm/cycle (brainstem, FH) to 0.1 mm/cycle (upper brain, AP,RL). To allow assessment of data consistency, 120 % of a full cardiac cycle were covered. Remaining scan parameters were: temporal resolution: 70 ms, in-plane resolution: 1-2 mm^2 and slice thickness: 4 mm. Time-invariant phase errors due to eddy-currents were eliminated by subtraction of the first time frame from the following ones. 5 healthy volunteers were examined on a Philips 1.5T Intera scanner (Philips Medical Systems, Best, The Netherlands).

Results

Displacement maps (Figure 1) could be acquired in all volunteers over the whole cardiac cycle and encoded in all three directions. The data revealed excellent periodicity with a mean difference in displacement between the first and last frame of the cycle amounting to (0.01 ± 0.005) mm in the brain stem. Comparison of maximum displacement measured by C-DENSE and CSPAMM + HARP in large uniformly moving areas such as the brainstem showed good agreement whereas values from neighboring areas with localized motion such as the cerebellum and the isthmus gyri cinguli differed between the two methods (Figure 2). To assess reproducibility one volunteer was scanned twice and good agreement of displacement data (with a root mean square of difference between the subsequent measurements of e.g. 0.017 mm in the pons) was found.

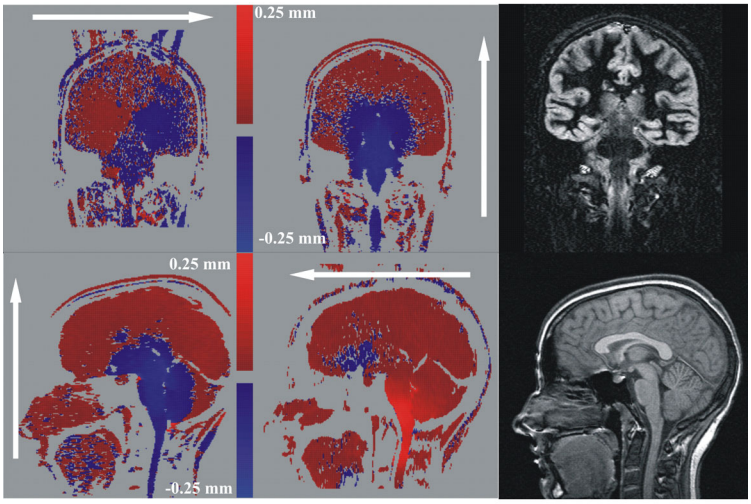

Figure 1: *Phase maps of a sagittal slice 200ms after the R-wave encoded with 0.5 mm/cycle. The mainly anterior caudal motion of the brainstem during systole is clearly visible as well as the medial displacement of the brain hemispheres which is likely to cause a pumping effect in the 3rd ventricle.*

Discussion

The proposed method for measuring brain motion revealed excellent reproducibility in the first 600 ms of the cardiac cycle up to very small motions. Evaluation of later cardiac phases was slightly compromised due to saturation effects but nevertheless showed good reproducibility across measurements. It is concluded that C-DENSE provides a potential means to investigate very small motions in the brain.

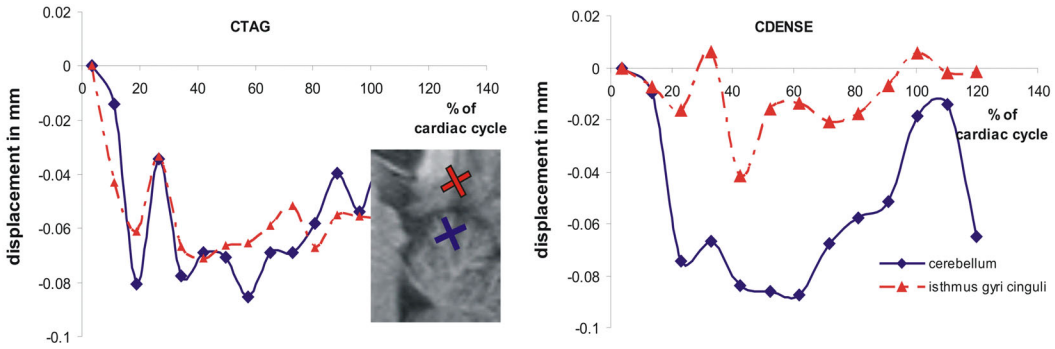

Figure 2: *Comparison of FH-displacement data acquired with CDENSE and CSPAMM combined with HARP (CTAG) of two neighboring but anatomically independent structures, separated by CSF. Whereas the two areas are clearly distinguished with CDENSE, CTAG lacks spatial resolution and the influence of surrounding CSF is significantly increased.*

Literature

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