Measuring Through Plane Strain in Brain Using Strain-Encoding (SENC) MRI

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Introduction: Many diseases of the central nervous system, such as hydrocephalus, Arnold-Chiari malformation, hydromyelia, and others are associated with abnormal cerebrospinal fluid (CSF) dynamics in the brain[1,2]. CSF is produced in the choroid plexuses of the brain and is drained mainly through the superior sagittal sinus. A periodic pulsatile motion governed by the cardiac cycle through the cerebral arteries is superimposed upon the steady flow caused by the CSF production. A controversy exists about fluid and pressure dynamics, and about how the brain responds to these changes in flow patterns and compression. Strain Encoding (SENC) has shown the ability to image through-plane tissue deformation to a high precision through time [3]. In this abstract, we propose the use of SENC to study the brain dynamics in response to the CSF circulation.

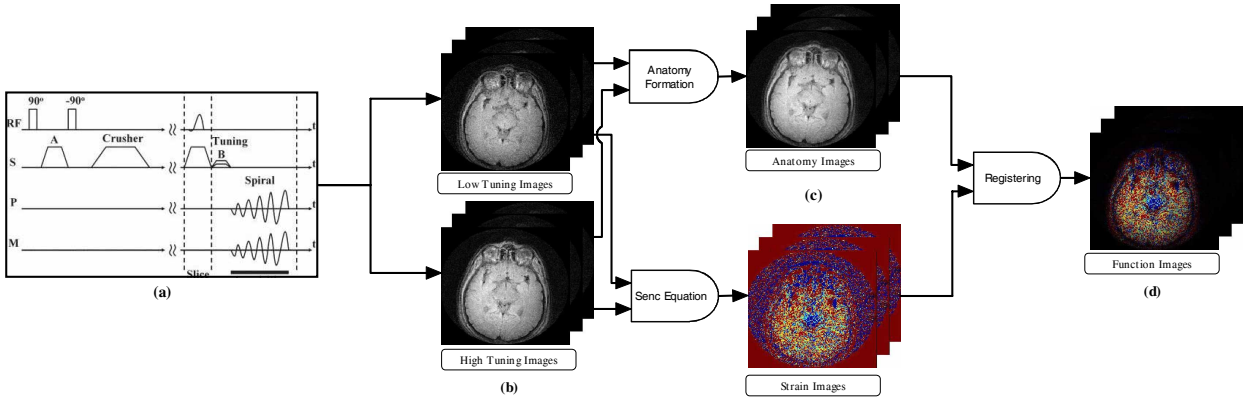

Fig. 1: Elements and principle of SENC technique. a) Typical pulse sequence, the tagging (modulation) gradient, shown as A, is applied in the slice-selection direction, and a tuning (demodulation) gradient, shown as B, is applied during the refocusing lobe of the slice-selection gradient. During readout the image is acquired at different tuning frequencies (S = slice selection, P = phase encoding, and M = measurement). b) Two sets of low and high tuning images are generated. c) Using the low and high tuning sets, strain images are generated using Senc equation [3] and anatomy images are calculated. d) Both anatomy and strain images are registered together to form the function set images.

Methods: A normal volunteer was imaged using the SENC pulse sequence on a clinical 3T MR whole-body system (Gyroscan Intera; Philips Medical System, Best, The Netherlands). Images were acquired with spatial resolution = 1.6*1.6mm and slice thickness = 8mm. Acquisition was synchronized after the R-wave with temporal resolution = 18msec, NSA =4. Low and high tuning frequencies were adjusted so as to capture deformation strain ranges from -5% to 5% and calculated as in [3]. The strain maps were then constructed from SENC raw images as in [3] and registered with the anatomy images to produce the functional images (Fig. 1).

Results And Discussion: Fig. 2 shows a series of functional images for an axial slice of the brain. Local and small strain areas (either compression or stretching) appear due to the small cerebral arteries, also a global tissue deformation appears due to the effect of the CSF circulation. Fig. 3 shows the strain curves for different points from the same slice. While all the points start nearly from the same strain values, the brain tissue at the blue points in the Mid-Brain area starts to stretch earlier than the other points. Also, the maximum stretching values that each group attains are different and depend on the distance from the center of the Mid-Brain.

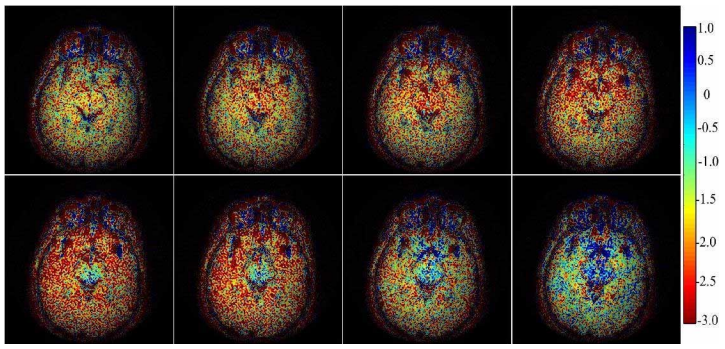

Fig. 2: Functional Image for an axial image of the brain. Times frames, from top-right are at 11, 51, 90, 130,169, 209, 248, 288 and 328 msec from the R-wave.

Conclusion: SENC technique was presented for measuring tissue deformation dynamics in the brain due to the CSF circulation. Tissue deformation due to the effect of the pulsation of the cerebral arteries and the effect of CSF circulation can be detected and measured. More analysis is needed to understand the relation between the two circulations and the regional deformations of the brain.

References: [1] Quencer RM, Post MJ, Hinks RS. Neuroradiology. 1990; 32:371-391.
[2] Greitz, D., et al, 1992. 34(5): 370-80.
[3] Osman N.F et al "Imaging longitudinal cardiac strain on short-axis images using strain-encoded MRI," Magn. Resn. Med. 46: 324-10 (2001).

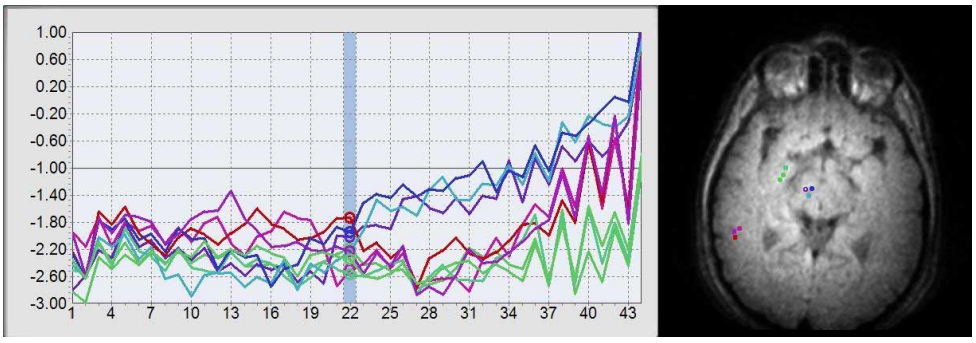

Fig. 3: Strain curves (Through plane strain VS. Time Frames) for different pixels in three different regions in the brain (Blue group in Mid-Brain, green group in Hippocampus, and red group in Temporal Parietal Lobe). Time scale is 18 msec per frame starting after the R-wave.