Accelerating MR Elastography: A Multi-Echo Phase Contrast Gradient Echo Sequence

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Introduction

MR Elastography (MRE) is known as a method for measuring elasticity of soft tissue [1]. To determine the tissue elasticity, visualization of mechanical waves induced into the tissue is required. Visualization of motion can be performed with a phase contrast sequence comprising gradients adapted to the induced sinusoidal oscillations. Single echo sequences suffer from long scan times. A significant reduction of scan time can be achieved by multiple signal readouts per excitation. The purpose of the present study was to implement a multi-echo phase contrast (PC) sequence and compare it to conventional single-echo sequences. Additionally, the sequence was tested with an in vivo MRE examination in the biceps of healthy volunteers.

Methods

A piezoelectric actuator [2] was employed to induce mechanical waves into an Agar gel phantom of 2.5% concentration. A multi-echo PC FLASH sequence was implemented with motion-sensitizing gradients (MSG) allowing for acquisitions with different echo train lengths (ETL). All images were acquired with a 1.5T SIEMENS Sonata system. The scan parameters for all acquisitions were: TR 40 ms; matrix 256x256; FOV 200x200 mm^2; flip angle 15°; MSG cycles 1; MSG amplitude 25 mT/m; mechanical frequency 200 Hz. The ETL was varied from 1 to 4. TE was set to the lowest possible value to ensure the highest SNR for a given sequence: 8.95 ms, 11.3 ms, 10.7 ms, and 10.5 ms for an ETL of 1 - 4, respectively. The single-echo sequence was used as reference. Images with higher ETL were compared with respect to SNR and artifacts. Profiles through the shear waves in the phase images were analyzed with MATLAB (The MathWorks, Natick, MA) to determine the wavelength which is needed for elasticity calculation. Finally, phase images with an ETL of 1, 2, and 4 were acquired in the volunteers biceps.

Results

The upper images Fig. 1A – 1D show magnitude images acquired in the phantom with an ETL of 1 through 4. Below each magnitude image the corresponding phase images can be seen. The time reduction from the multi-echo sequence was almost proportional to the ETL. Scan times were 22 s, 11 s, 7.4 s, and 5.8 s for ETL 1 - 4, respectively. The measured wavelength was almost identical for all ETL (44 mm, 43 mm, 43 mm, 43 mm for ETL 1-4). Assuming a density of 1000 kg/m^3, this results in a shear modulus of 81.4 kPa to 85.2 kPa, respectively, which also correlates with published data [3]. Ghosting artifacts in the images increased slightly with higher ETL. Neither the magnitude images nor the profiles through the phase images yield a significant loss of SNR.

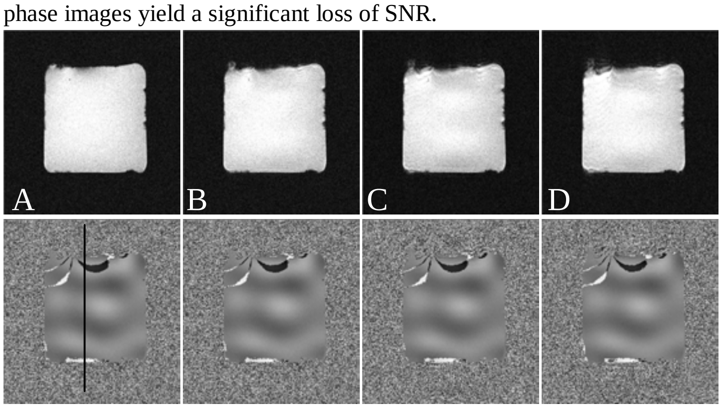

Fig. 1: Sagittal magnitude images with ETL 1-4 and corresponding phase images (phase offset 0°).

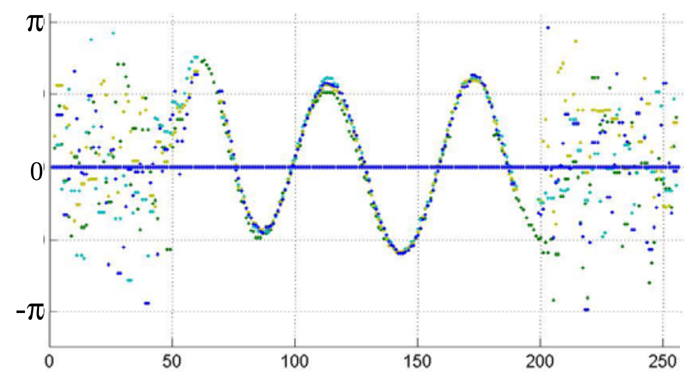

Fig. 2: Superimposed vertical profiles along the center of the four phase images (see Fig. 1) ETL 1-4 with phase offset of 45° shows similar waveforms in all measurements.

The phase images acquired in the biceps are shown in Fig. 3.

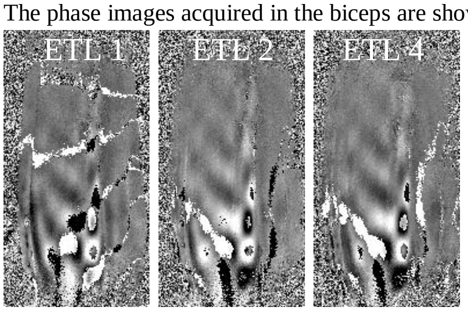

Fig. 3: Coronal phase images of a human biceps with ETL 1, 2, and 4. The phase offset was 0°. To avoid phase wraps, a suitable phase unwrapping algorithm should be applied to all the images.

Discussion

These results demonstrate that a multi-echo sequence is suitable for MRE. It provides equivalent elasticity values in significantly reduced time, compared to a single-echo sequence. Almost no reduction of image quality was detected with an ETL of 1 through 4. Higher ETLs will provide even shorter acquisition times, however, the potential degradation of image quality has to be addressed in further investigations

References

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