Simple MR Elastography: A Gradient-Echo type Multiecho MR Sequence

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Introduction

In this work we report on the development of a new technique for simple MR Elastography (MRE) sequence based upon a gradient-echo type multiecho MR sequence. The conventional MRE pulse sequence was to build the several bipolar magnetic field gradients (motion sensitizing gradient: MSG) into an imaging pulse sequence, which prolongs echo time (TE). A prolongation of TE degrades signal to noise ratio (SNR), and increases the magnetic susceptibility artifacts. We propose the simple MRE method that does not need built-in MSG (no prolongation of TE), to avoid these demerits. A gradient-echo type multiecho imaging sequence use a series of echoes acquired as a train following after a single excitation pulse. Multiple symmetrical gradient-echoes can be acquired by the symmetrical negative-positive switching readout gradient lobes; typically it is useful for shortening acquisition time. Also, a multiecho sequence acquires images with different weightings and / or echo times and is used to obtain various images without increasing the acquisition time. By adjusting the period of negative-positive readout gradient lobes, the TE of multiecho sequence can be changed. Thus, the frequency of actuator-generated vibration and the readout gradient lobes were synchronized. The readout gradient lobes have the similar function as MSG. The purpose of this study was to test the non-MSG multiecho MRE method by using clinical MR imager, and was to examine the potential of this method through agarose gel phantom experiments and volunteer studies.

Materials and methods

Figure 1 shows a non-MSG multiecho MRE sequence. In contrast to the major benefit of the multiecho imaging, which is shortening acquisition time, we use the other benefit, separate images are produced from each echo of the train with different TE (green dashed lines). When the period of actuator-generated vibration and the readout gradient lobes are in agreement (red dashed lines), the MSG-like effect serves as the maximum. Moreover, since the later generated echo experienced greater MSG-like effect ($1^{st}<2^{nd}<3^{rd}$...), then the non-MSG MRE multiecho sequences acquires images with different MSG-like effects without increasing the acquisition time. In other words, the user can choose from different MSG-like weighted images, after MR scans. All MRE data were acquired on a 3.0-T clinical imager (Achieva, Philips). TR: 50ms, TE-interval (blue dashed lines): 5.0ms (ex. 2.4-7.4-12.4…ms, correspond in vibration frequency 100Hz), FA: 20degree, Matrix: 256×256, vibration frequency: 100Hz, vibration phase offset: 8, total acquisition time: 3m25s, vibration-type: continuous vibration (synchronized with TR, shear motion) with pneumatic actuator. All elastograms were produced by Local Frequency Estimate (LFE) algorithm freeware (MRE/Wave, MAYO CLINIC).

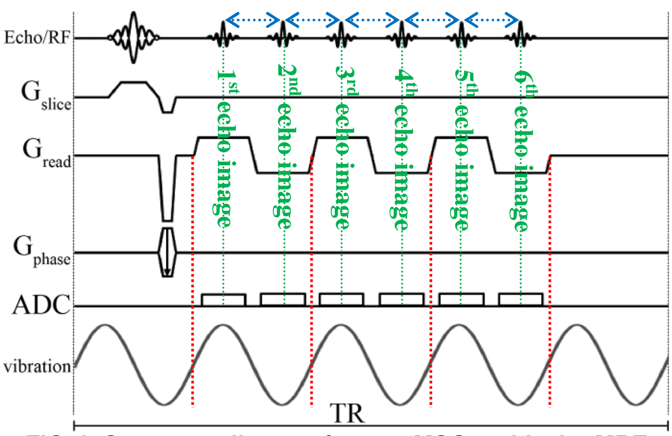

FIG. 1. Sequence diagram for non-MSG multiecho MRE

Results and discussion

Figure 2 shows the profile plots through a vertical line (black arrow) of each wave images (MR pahse images) with 0.75% agarose-gel phantom. The vibration frequency (100Hz) was in accordance with the TE-interval (5ms). Each TE sets 2.4ms, 7.4ms, 12.4ms, 17.4ms, and 22.4ms for number of echo 1st, 2nd, 3rd, 4th, and 5th, respectively. The sensitivity of the vibration was increase at later echo, but the later echo image revealed susceptibility artifacts arise from prolongation of TE (not shown).

Figure 3 shows the each echo magnitude images (top row), wave images (middle row), elastograms (bottom row) obtained at volunteer thigh, respectively. The thigh was sandwiched in dual stethoscope-like pads. By the non-MSG multiecho MRE acquisitions, several different wave sensitivity images can be obtained, from which the user can choose later. As in the case of agarose-gel phantom experiments, the sensitivity of the vibration was increase at later echoes. It was effective for detecting the wave at the deeper tissue. Since the transverse relaxation time of tissues was shorter than the agarose-gel phantom, the later echo image suffered susceptibility artifacts and low SNR arising from the prolongation of TE. In particular, the choosing of later echo wave image cannot be used when imaging short T2 relaxation components in the imaging object. As shown in Figure 3. the both sides of thigh bone indicates high stiffness area (lateral / medial vastus muscle). This may be caused by compression between the thigh bone and dual stethoscope-like pads.

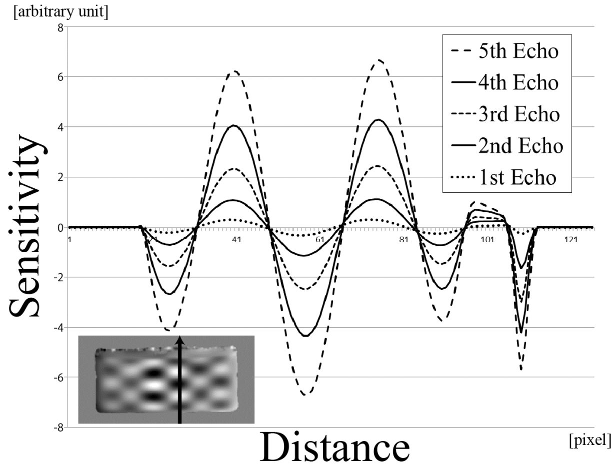

FIG. 2. Vibration sensitivity of non-MSG multiecho MRE

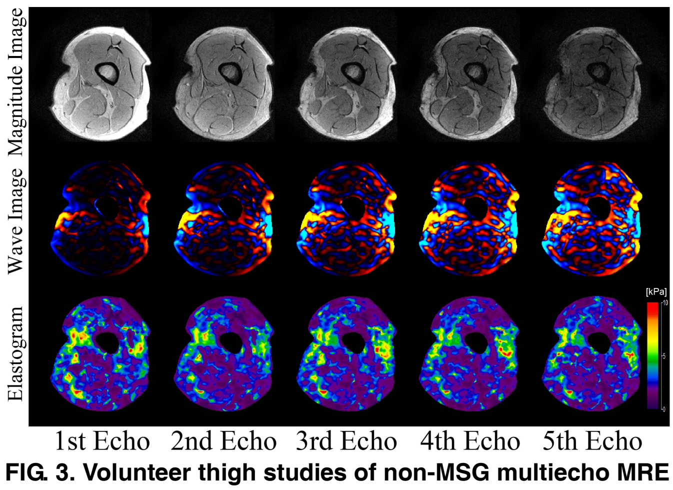

FIG. 3. Volunteer thigh studies of non-MSG multiecho MRE