Temporal phase transition via fractional wave cycle TR in MR elastography

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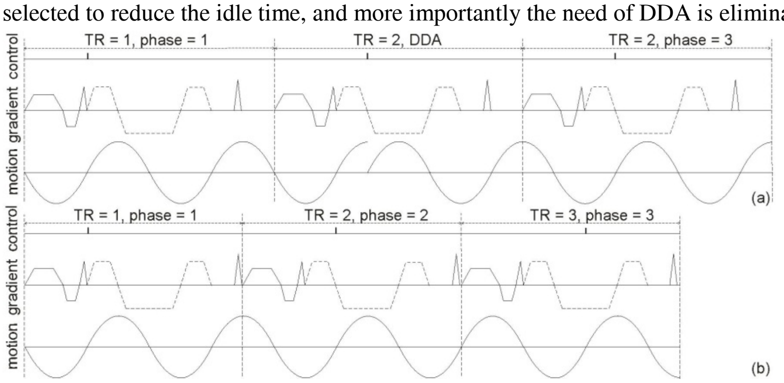
Introduction MR elastography (MRE) allows the stiffness of internal human organ to be non-invasively assessed, and has been clinically used in the diagnosis of fibrosis and cirrhosis (1). In MRE, an external driver is used to generate a periodic wave and applied to the subject. A key factor for high quality elastogram is accurate synchronization of the external wave and the motion encoding gradient (MEG), as reconstruction of the elastogram requires several temporal phases with different initial phase (time) offsets between the external wave and the MEG. To achieve this, a TR that is the multiple of the wave periods is usually used. In this way, not only the flexibility for TR selection is limited, also additional discarded data acquisitions (DDA) are required during in the scan. Both factors amount to prolonged scan time, which is a critical issue in MRE as breath hold is often performed in liver scans. In this work, we propose a new method that uses a TR of fraction of the wave cycle to achieve transition between different temporal phases. In this way, the flexibility of TR selection may be improved and the DDAs may be removed.

Method The pulse sequence of a typical MRE acquisition is illustrated in Fig.1.(a). In this example, a sinusoidal external wave and a TR of a 2 wave cycles are used. The gradient axis shows the MEG as dashed lines. The control axis contains the trigger pulse that is used to trigger/reset the driver for synchronizing the external wave and MEG. In this way, there is normally a considerable idle time period in each TR, as the TR has to increase in the step of wave cycle that is in the range of 10~20ms depending on the wave frequency. More importantly, in the transition from one temporal phase to the other (TR = 1 to 2, Fig.1.(a)), the change of the position of the trigger pulse results in an abrupt change in the wave, which makes the data acquisition in this TR unusable and considered to be discarded data acquisition (DDA). Normally, additional DDAs are needed to allow the wave to settle within the subject before the acquisition of next phase begins. The DDAs may take a considerable portion of the scan time on single shot EPI based MRE. This unnecessarily prolongs the breath hold time of the patient.

An alternative way for the transition of temporal phases is to use a fractional TR as illustrated in Fig.1.(b). In order to achieve a phase shift of 0.25 wave cycle (assuming 4 temporal phases), a TR of 1.75 cycles of the wave is used. In this way, the relative temporal position of the MEG and wave automatically shifts by 0.25 cycle in consecutive TRs with no discontinuity of the wave in between the phases. Then the TR may be more flexibly selected to reduce the idle time, and more importantly the need of DDA is eliminated.



Methods The proposed method is implemented on a GE 1.5T body scanner. Phantom (filled with agar gel) and volunteer scans (liver) were performed to verify the validity of this method. Consent form has been obtained prior to volunteer scan. A 60Hz acoustic sound wave was generated and applied during the scan. MRE scans with 4 temporal phases were performed with breath hold using both conventional and modified FGRE based pulse sequences. In the former case, a TR of 50 ms (3 cycles) was used and 4 DDAs were inserted in between the phases; in the latter case a TR of 37.5ms (2.25 cycles) was used and no DDA was used. The resulting scan times were 20s and 14s respectively with an ASSET factor of 2.

Figure 1: pulse sequences of (a) product implementation (b) proposed implementation of the MRE. Three consecutive TRs in each case are shown. In (a), TR =2 experiences discontinuous wave encoding and hence is DDA. Such issue is avoided in (b).

Results The processed waveform images of the phantom and volunteer scans are shown in the top and bottom of Fig.2 respectively. It is seen that the processed phase images corresponding to the four different temporal phases are almost identical, and the slight difference in volunteer images may be attributed to different breath hold conditions. Hence equivalent motion encoding was achieved despite a shortened TR and no DDAs were used.

Discussion and conclusion An improvement of the pulse sequence implementation of MRE is proposed. Instead of relying on re-triggering the external wave in every temporal phase, the transition from one temporal phase to the other is achieved by sliding the relative temporal positions of the external wave and MEG. In this way, the TR may be more flexibly selected and also the need of DDAs is eliminated. The scan time reduction may be used to improve the patient's comfort in breathhold or acquire additional temporal phases.

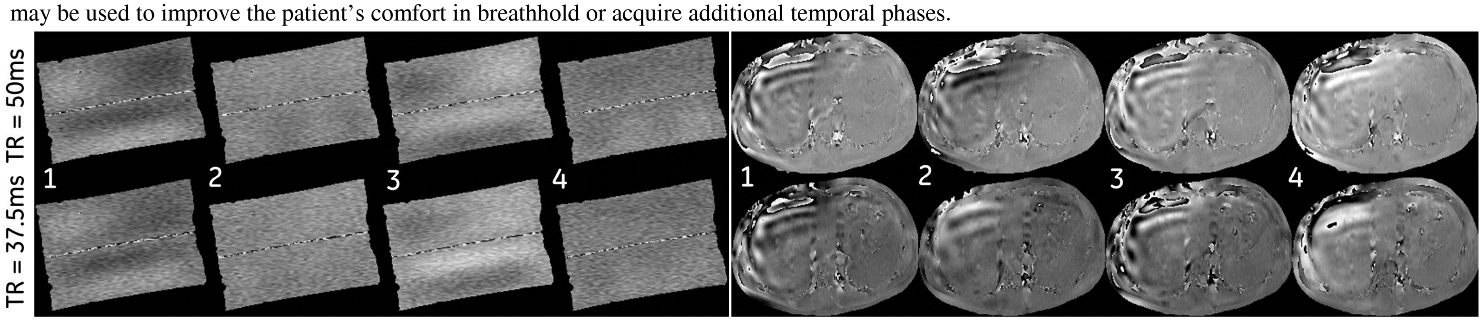


Figure 2: Motion waveform from 4 temporal phases (as numbered) using current (above) and proposed (below) motion encoding method.

Reference (1) Mariappan, et al., Clinical Anatomy 2010, 23(5):97-511