Magnetic Resonance Elastography with a Wireless Synchronization Pneumatic Vibration System

Tomokazu Numano[1], Kazuyuki Mizuhara[2], Yoshihiko Kawabata[3], Toshikatsu Washio[4], and Kazuhiro Homma[4]

[1]*Radiological Sciences, Tokyo Metropolitan University, Arakawa, Tokyo, Japan,* [2]*Mechanical Engineering, TOKYO DENKI UNIVERSITY, Adachi, Tokyo, Japan,*
[3]*Takashima Seisakusho Co.,Ltd, Hino, Tokyo, Japan,* [4]*National Institute of Advanced Industrial Science and Technology, Tsukuba, Ibaraki, Japan*

Introduction

In this work a new MR Elastography (MRE) technique which can be performed on conventional MRI was developed. One of the authors has reported that (ISMRM 2013:2437) a conventional gradient echo type multiecho sequence can be used for simple MRE sequence as a substitute for a dedicated MRE sequence. In this sequence, motion sensitizing gradient (MSG) is not necessary, but the vibration frequency is set to an integer multiple of 1/TR and synchronized with the vibration. To synchronize the pneumatic vibration with TR, we used the first shot of the RF excitation pulse. In fact, we used the TTL signal of the first shot from the RF power amplifier which is not available in conventional MRI system. In this work, a wireless TR synchronization system consists of high-frequency radio receiver and a plain dipole antenna tuned to the RF excitation frequency was developed. The leak RF signal received via the dipole antenna, in the magnet room was available as the TR synchronization trigger then any electrical wiring from the MRI electronics is required. The fusion of the simple MRE sequence and the wireless synchronization pneumatic vibration system make it possible to construct the MRE system in any conventional MRI system. The feasibility and potential of this simple MRE method with the wireless synchronization pneumatic vibration system was examined by using clinical MR imager, through on agarose gel phantom experiments and volunteer studies.

Materials and methods

Figure 1 shows the MRE system with the wireless synchronization pneumatic vibration system. The orange color and green color icons show a conventional MRI system, and a pneumatic vibration system respectively. In all MRE, the MRI are acuired at two or more different vibration phases to snapshot the propagation of the waves, some temporal samples spaced equally over a period of the wave motion, to show the propagation of the wave in MRE experiments and to permit processing of the data through time. In our MRE system, the vibration phase offset was controlled by the waveform generator since the conventional MRI system doesn't have the trigger input to start the MRI sequence. In our previous work, vibration was started with the TTL signal of the first shot of the RF excitation from the RF power amplifier via a cable (blue dash line). However, most of the conventional MRI system doesn't have this TTL output so some modification or current pick up was needed. In this work, to avoid any modification to the MRI system, the leak RF signal was used to trigger the vibration. First, we put the handmade blade (dipole) antenna in the magnet room, and it connected to a multiband receiver (ALINCO DJ-X7). The multiband receiver was tuned to a 3.0-T proton resonance frequency of 127.75MHz in amplitude modulation mode. The received leak RF excitation pulse was demodulated to the envelope signal of the RF pulses in audio frequency and available through earphone jack. Then, the signal was amplified, filtered and converted to the TTL signal by a comparator. Finally, this TTL signal is used to trigger the sine wave generator system (LabVIEW, USB-6221) to synchronize the pneumatic vibration system with the MRE sequence. The first shot of the leak RF excitation pulse was used as a trigger signal. All MRE data were acquired on a 3.0-T clinical imager (Achieva, Philips). The gradient echo type multiecho MRE sequence parameter were TR: 40ms, 1st TE : 2.3ms, TE-interval: 6.0ms, echoes: 3, FA: 20degree, Matrix: 256×256, vibration frequency: 50Hz, vibration phase offset: 8, total acquisition time: 2m44s, vibration-type: continuous vibration (TR cycle shear motion). All elastograms were produced by Local Frequency Estimate (LFE) algorithm freeware (MRE/Wave, MAYO CLINIC).

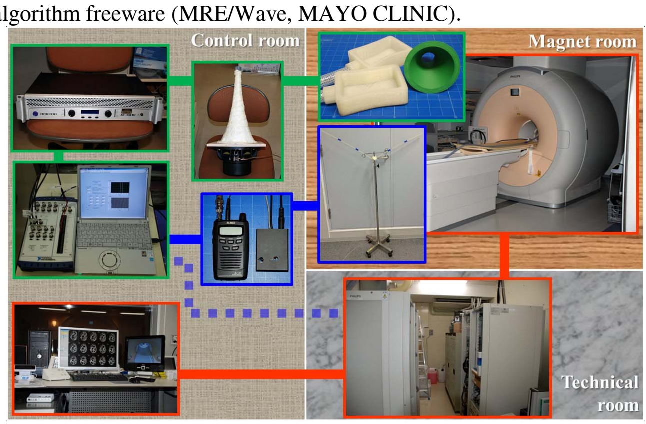

FIG. 1. Wireless synchronization MRE system

Results and discussion

Figure 2 shows the waveform of leak RF pulse via the handmade dipole antenna with oscilloscope direct measurement. We can see two types of RF pulse, the regional saturation technique (REST) pulse which was used to avoid flow artifacts and the imaging excitation pulse. The time interval between each RF pulse was 40ms, because we set the TR of the sequence for 40ms. The wireless system has enough sensitivity to make the trigger signal. Figure 3 demonstrates the wave image (c), and elastogram (d) obtained from wireless synchronization MRE system at volunteer main psoas muscle, respectively. These images were the magnitude image (a) overlaid with the wave image or the elastogram. Fig. 3b shows the position of vibration pads and the region of psoas muscle. It would appear that, because the main psoas muscle attached to lumber spine, the vibration of lumber spine efficiently transferred vibration to the main psoas muscle (Fig. 3c). It is confirmed that fusion of the wireless synchronization vibration system and the gradient echo type multiecho MRE sequence enables the conventional MRI to perform MRE without any modification to the exicting MRI system, This MRE technique does not require a dedicated MRE sequence (built-in MSG) and an electrical wiring, and it can be performed by conventional MRI.

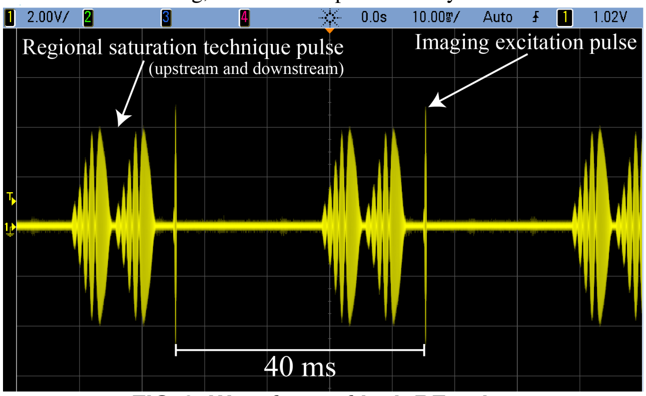

FIG. 2. Waveform of leak RF pulse

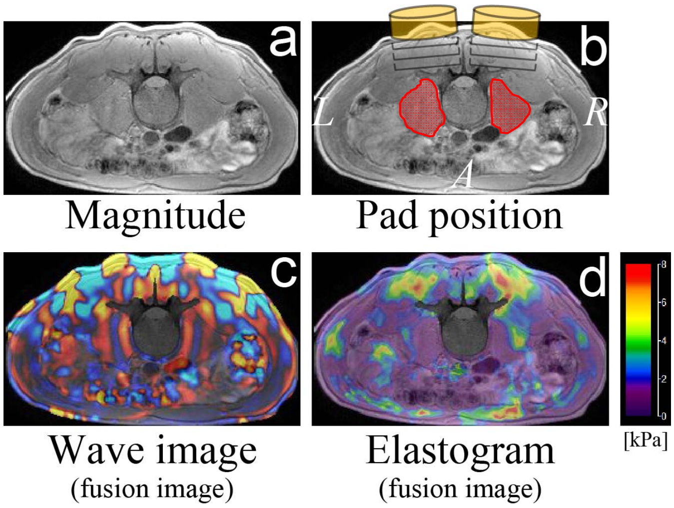

FIG. 3. Volunteer study of wireless synchronization MRE