Pulse sequences for MRE

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Palpation is standard clinical practice for assessing the health of tissue near the body surface. MR elastography (MRE) (1,2) allows quantifying the viscoelasticity of soft tissue deep inside the body and has the potential of helping to detect pathologic tissue alterations.

Technically, MRE is based on the application of external vibrations and measuring the tissue's shear-response by motion-sensitive MRI. The vibration frequency has to be low (for most in vivo studies below 100 Hz) in order to mitigate damping of the shear waves due to viscosity. Standard spin-echo and gradient-echo MRE sequences employ bipolar motion-encoding gradients (MEG) whose duration matches the mechanical vibration period (3). As a result low vibration frequencies automatically require long echo times and therefore result in high signal loss due to T2 dephasing. This problem has been addressed by several investigators using the read-out gradients for motion sensitization (4-6). The application of this approach has been limited thus far, since the sensitivity of the sequence to motion depends on the receiver bandwidth and only in-plane motions can be measured. For this reason, Rump et al. used MEG's for a much shorter time than one vibration period (7,8), which exploits only fractions of one vibration cycle for motion encoding. Despite a lower motion sensitivity, fractional MRE measures a higher phase-to-noise ratio in soft and viscous materials than classical MRE by using a much shorter repetition time in the order of standard steady-state MRI. Broad-bandwidth MEG's as applied in fractional MRE can be employed for polychromatic motion encoding capable of monitoring the dispersion of the speed and the damping of shear waves in viscoelastic materials (9). This concept is especially beneficial in combination with fast single-shot EPI-MRE because a high temporal resolution of the wave propagation can then be measured within short scan times (10). Other recent sequence developments in MRE comprise nulling first MEG moments (11), keyhole (12), pencil beam (13) and tagging MRE (14) as well as MRE on 7T whole-body MRI machines (15).

1. Muthupillai R, Lomas DJ, Rossman PJ, Greenleaf JF, Manduca A, Ehman RL. Magnetic resonance elastography by direct visualization of propagating acoustic strain waves. Science 1995;269(5232):1854-1857.
2. Plewes DB, Betty I, Urchuk SN, Soutar I. Visualizing tissue compliance with MR imaging. J Magn Reson Imaging 1995;5(6):733-738.
3. Muthupillai R, Ehman RL. Spectrally-Selective Gradient Waveforms: Applications in MR Elastography. In: Proceeding of the 6th Annual Meeting of ISMRM. Sydney. 1998. p 2180.
4. Weaver JB, Qin X, Doyley MM, Van Houten EE, Kennedy FE, Paulsen KD. Encoding Harmonic Motion in MR Elastography Using the Imaging Gradients. In: Proc 11th Annual Meeting ISMRM. Toronto. 2003. p 1077.
5. Grimm RC, Kugel JL, Ehman RL. Improved Phase to Noise Ratio for Short T2* Spins in MRE. In: Proc 12th Annual Meeting ISMRM. 2004. p 572.
6. Bieri O, Maderwald S, Ladd ME, Scheffler K. Balanced alternating steady-state elastography. Magn Reson Med 2006;55(2):233-241.
7. Rump J, Klatt D, Braun J, Warmuth C, Sack I. Fractional encoding of harmonic motions in MR elastography. Magn Reson Med 2007;57(2):388-395.
8. Rump J, Warmuth C, Braun J, Sack I. Phase preparation in steady-state free precession MR elastography. Magn Reson Imaging 2008;26(2):228-235.
9. Klatt D, Hamhaber U, Asbach P, Braun J, Sack I. Noninvasive assessment of the rheological behavior of human internal organs using multifrequency MR elastography: A study of brain and liver viscoelasticity. Phys Med Biol 2007;52(24):7281–7294.
10. Braun J, Bernarding J, Tolxdorff T, Sack I. In vivo magnetic resonance elastography of the human brain using ultrafast acquisition techniques. In: Proc 10th Annual Meeting ISMRM. Honolulu. 2002. p 2597.
11. Grimm RC, Yin M, Ehman RL. Gradient Moment Nulling in MR Elastography of the Liver. In: Proc 15th Annual Meeting ISMRM. Berlin. 2007. p 961.
12. de Greiff A, Maderwald S, Ladd ME. Accelerating MR Elastography by Means of Keyhole Imaging. In: Proc 14th Annual Meeting ISMRM. Seattle. 2006. p 3038.
13. Glaser KJ, Felmlee JP, Ehman RL. Rapid MR elastography using selective excitations. Magn Reson Med 2006;55(6):1381-1389.
14. Sack I, Hamhaber U, Rump J, Papazoglou S, Klatt D, Braun J. Coherent motion preparation of the magnitude signal in MR elastography. In: Proc 15th Annual Meeting ISMRM. Berlin. 2007. p 958.
15. Maderwald S, Kraff O, de Greiff A, Zenge MO, Stock F, Lanz T, Ladd ME. In Vivo and In Vitro 7T MR Elastography with Parallel Imaging. In: Proc 15th Annual Meeting ISMRM. Berlin. 2007. p 1254.