In Vivo and In Vitro 7T MR Elastography with Parallel Imaging

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Introduction:

Magnetic resonance elastography (MRE) is a phase contrast-based method for observing shear waves propagating in a material to determine its stiffness [1]. At 1.5T, the feasibility of this method (ex and in vivo) has already been demonstrated. In this work, we use a 7T scanner for imaging to profit from the higher signal to noise ratio (SNR) at higher field strength. Additionally, parallel imaging (pMRI) was implemented into the conventional sequence and adapted to 7T. At 1.5T MRE is often SNR limited, so that pMRI is inappropriate. Benefits from parallel imaging include improvement in the speed of the MRE acquisition or an increase in the resolution within the same scan time, and reduction of the overall specific absorption rate (SAR). Phantom measurements with and without pMRI are used for comparison. Finally, we show results in the brain of two healthy volunteers in vivo.

Methods:

A whole-body human 7 Tesla scanner (Magnetom 7T, Siemens Medical Solutions, Erlangen, Germany) equipped with a high performance gradient system capable of 45 mT/m maximum amplitude, a slew rate of 220 mT/m/ms, and an 8-channel transmit-receive head coil (Rapid Biomedical GmbH, Würzburg, Germany) were used. This transmit-receive coil was developed for 7 T high-resolution in vivo imaging of the human head and consists of 8 elements distributed equally around a cylinder, allowing pMRI primarily in two spatial directions.

To introduce mechanical waves into the region of interest, a piezoelectric oscillator [2] was used. The mechanical excitation was performed with a frequency of 200 Hz and amplitude of 200 µm via an oscillator lever with a Plexiglas appendage in physical contact with the phantom (agar, background 1% and two inclusions 2%). The oscillation was in the right to left direction.

A modified gradient echo phase contrast (PC) sequence with motion-sensitizing gradients (MSG) freely selectable in size, shape, and orientation, which are synchronized to the mechanical vibration, is our standard sequence for MRE. Adaptations to the source code allowed adding additional parameters for the self-calibrating parallel imaging algorithm GRAPPA [3]. Typical scan parameter settings were: TR 40 ms; TE min; matrix 256x256; FOV 200x200 mm^2; MSG cycles 3; MSG amplitude 10$mT \bullet m^{-1}$, slice thickness 3 mm, 8 transverse slices. The GRAPPA algorithm with a reduction factor R = 2 and up to 50 reference lines was used to reduce scan time for the pMRI measurements; all other scan parameters were held constant between both sequence types to ensure comparability. For comparison, the resulting phase images were examined regarding equivalency (wave peak and trough appearance). Additionally, the local frequency estimation (LFE) technique [4] was used to determine shear wavelength and hence to estimate the shear modulus of the tissue. The shear modulus for each sequence was taken as the average reconstructed elasticity in identically placed ROI's.

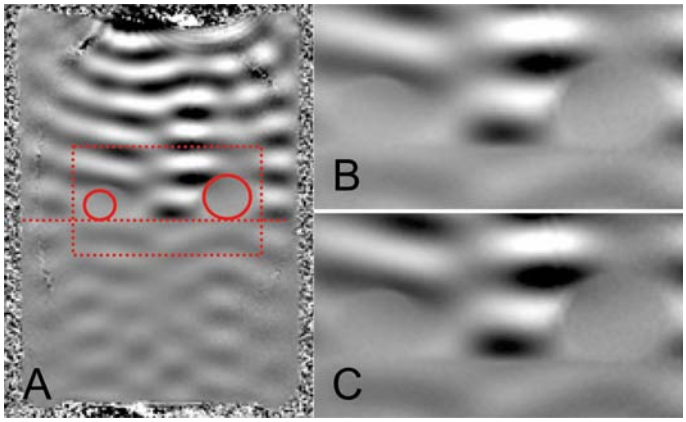

Fig.1: A: Phase image of entire phantom. Marked are the two inclusions, the zoom areas shown in B (no pMRI) and C (pMRI), and division line between upper and lower half due to fabrication. Note: No difference between wave propagation in B and C is seen.

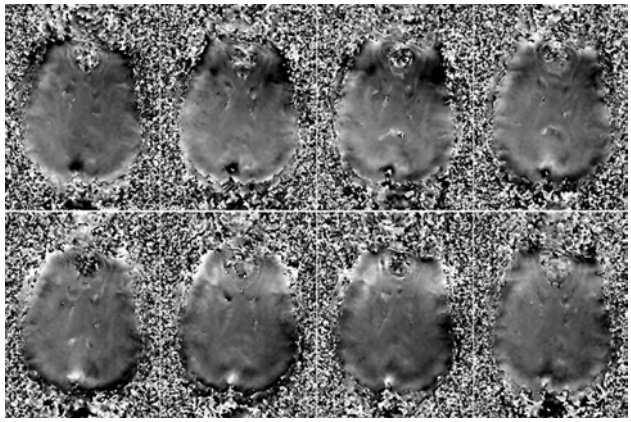

Fig.2: In vivo phase images with different phase offsets (0°-315°). Wave propagation through the tissue is evident. Excitation frequency 83 Hz, amplitude 600 µm.

Results:

Due to the intrinsic higher SNR at 7T, sufficient SNR for MRE was provided by the RF coil for both sequence types. GRAPPA reduces the acquisition time of the pMRI measurement by nearly a factor of 2. A good agreement in the subjective comparison of wave peak and trough appearance was found. The averaged elasticity values, represented by the shear modulus, were approximately 14 kPa and 55 kPa for the background and inclusions for both measurements, respectively. The in vivo scans showed the expected wave propagation pattern.

Discussion:

The present study clearly demonstrates that the transverse acoustic strain waves generated by the piezoelectric oscillator were well visualized at 7T by both sequence types. For the examined agar concentrations, we found consistent results with the published elasticity values [5] at 1.5T. Thus, parallel imaging seems suitable for MRE at 7T, since it provides equivalent elasticity distributions in significantly reduced time. Further investigations should be done to prove the feasibility of the method for in vivo measurements at 7T. Reported differences in in vivo stiffness values (but with identical elasticity distributions) [6] when using pMRI at 1.5T remain to be investigated. The overall advantages of the pMRI approach at 7T were its lower SAR values, lower g values for the coils, and the higher SNR. Therefore, higher acceleration factors can be used than at lower fields.

References:

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