Shear-wave scatter contrast enhancement in steady-state MR elastography

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Introduction: MR elastography (MRE) allows to test the mechanics of living soft tissue. The elastic information is deduced from phase images displaying the propagation of shear waves introduced from the surface of the body by acoustic actuators [1]. Typically, such shear wave images are inverted for producing spatially resolved elasticity maps denoted as elastograms [2].

Problem: Elastograms in MRE often suffer from limited spatial resolution due to strongly damped wave amplitudes and a low phase-to-noise-ratio in combination with large shear wavelengths. Therefore, it is difficult to detect small focal lesions or localized elasticity changes by means of MRE elastograms.

Objective: A simple method is proposed for analyzing minor amplitude changes of shear waves in steady-state MRE wave images. As result, a new image contrast is obtained that displays anatomical structures due to the externally applied motion. We ascribe the new contrast to differences in the mechanical impedance in heterogeneous tissue causing a scattering of shear waves [3]. The new shear-wave scatter contrast enhancement (SCE) is applied to in vivo MRE of the human brain and the liver.

Methods: *MR elastography experiments:* Mechanical excitation of the human brain was achieved by a nod motion of the head via bite bar using 20 cycles of 65 Hz vibrations. For MRE image acquisition a modified EPI sequence [4] was used incorporating one cycle of 65 Hz motion encoding gradient. For in vivo liver-MRE 51 Hz harmonic oscillations were guided via carbon fiber rod onto the abdomen surface of two volunteers. The mechanical excitation was continuously applied during data acquisition by a modified balanced SSFP-sequence [5]. All experiments were run on a 1.5T Siemens Sonata scanner. 20 phase-difference wave images were acquired with incremented trigger delay between wave generator and motion encoding gradient. Total experiment time was approximately 2 minutes for both brain and liver.

Shear-wave scatter contrast enhancement (SCE): The MRE wave image was spatially derived along rows and columns and then recombined to a single magnitude image of both derivatives. The resulting image was subjected to a 2D spatial high-pass filter with threshold above the wavelength of the transmitted shear wave. The entire procedure is demonstrated in fig.1.

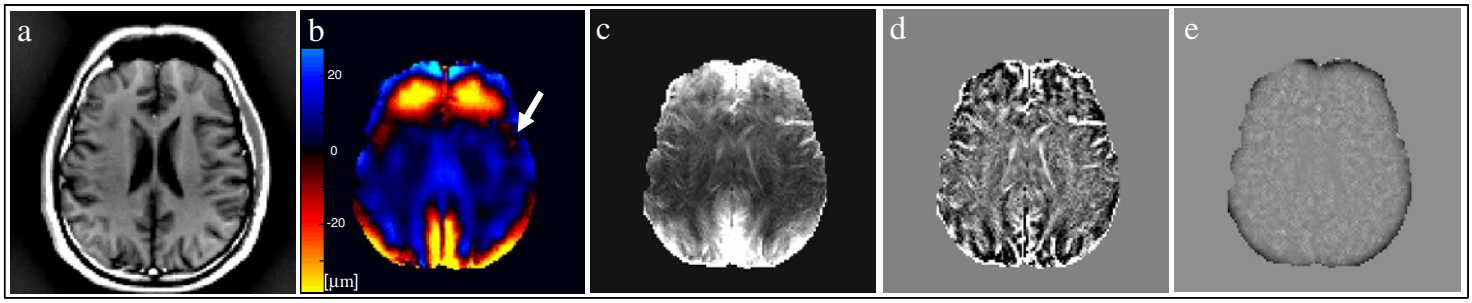

Fig.1: Application of shear-wave scatter-contrast enhancement (SCE) to in vivo MR elastography on the human brain. **a:** Transversal T_1w MR-image for anatomical compliance. **b:** Phase-difference MRE wave image showing out-of-plane deflection due to bite-bar actuation of a volunteer's head. Note, some substructures of the wave amplitudes are already visible without further treatment of the MRE-data (see arrow). **c:** The magnitude of the gradients along image rows and columns enhances steep amplitude changes so that shear wave scattering becomes prevalent in the image contrast. **d:** SCE-image obtained from fig.1c by application of a spatial high-pass filter for eliminating the transmitted shear waves. **e:** For comparison, the SCE-method applied to the same brain-MRE experiment but without head vibrations showing that the scatter contrast obtained in fig.1d is exclusively based on tissue motion..

Results and Discussion: An MRE phase-image contrast was produced by the new SCE-method that i) enhances steep amplitude changes and ii) eliminates the shallow sinusoidal gradient of low-frequency shear waves. In vivo brain-MRE experiments with and without vibrations demonstrated that SCE yields an image contrast that is related to mechanical properties of the tissue. With regard to anatomical structures visible in T_1w-images of the same brain slice we belief this contrast is due to diffuse scattering of shear waves at gray and white matter interfaces and to backscattering at the brain surface. In vivo liver MRE revealed a pronounced SCE-intensity in a cystic degenerated liver (fig.2). Deviating tissue impedances in cysts and liver generated steep wave amplitude changes which were exploited by SCE. Although it was not shown here, it is principally possible to derive elastic parameters from SCE-amplitudes similar to [3]. *Limitation of the method:* The scatter contrast is scaled by the wave amplitude. Thus, the SCE-signal depends on the penetration depth of the shear waves. This limitation is mitigated by the possibility to further decrease the vibration frequency (< 50Hz) for avoiding damping of the waves through viscosity.

Conclusion: Scatter contrast enhancement provides a simple means to gain elasticity information with high spatial resolution independently from the shear wavelength of MRE wave images. It is an image-based method applicable to conventional steady-state wave images and thus, it is possible to retrospectively derive information about shear wave scattering from existing MRE data. The new method is useful for detecting focal changes of the elasticity which might indicate pathologies.

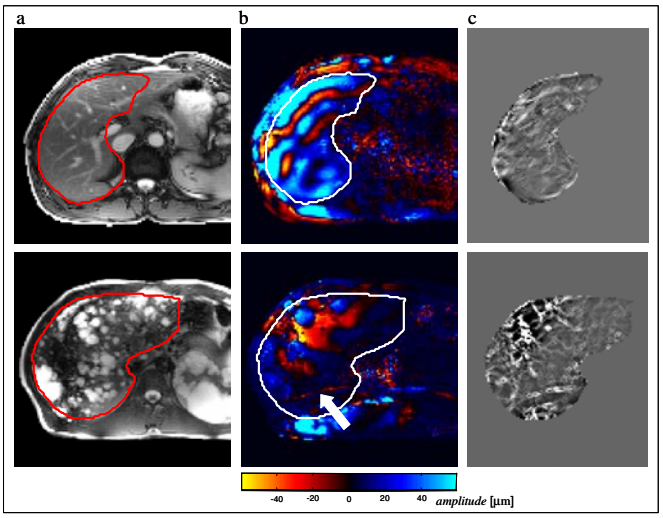

Fig. 2: Application of SCE to in vivo liver MR elastography. Two subjects with healthy (upper row) and polycystic diseased liver (lower row) were examined. **a:** Magnitude images for anatomical information. **b:** Phase-difference wave amplitudes (out-of-plane deflection). The arrow highlights signal distortions due to vibrations. **c:** SCE-images calculated from fig.2b showing moderate wave scattering in normal liver and a high scatter amplitude in parts of cystic liver tissue.

References:

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