High-Resolution MR Elastography of Human Skin

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Introduction

Magnetic resonance elastograpy (MRE) is a phase contrast-based method for observing shear waves propagating in a material to determine its stiffness. In vivo studies in skeletal muscle, in the breast and in the brain have already demonstrated the feasibility of this method.

In this work, MRE is applied to the skin and the subcutaneous fat to quantify the elasticity. We studied the wave propagation in the skin with the long-term goals to characterize melanoma, to obtain information on age dependence as well as to evaluate effects of skin cremes. To visualize microscopic structures within the skin, a high spatial in-plane resolution of about 40-100 µm is required for imaging. To achieve high SNR in such tiny voxels, the use of a dedicated surface receive-coil is mandatory.

Methods

All examinations of the nine volunteers (mean age 33, range 26 to 40) without abnormalities in the region of interest were performed on a 1.5 T (SIEMENS Magnetom Sonata) scanner using a custom made surface coil (Fig. 1) [1]. This RF receive only coil was developed for high-resolution in vivo imaging of human skin. The surface coil has a very low-noise linear 2-turn with a 18 mm-diameter loop. For imaging, a modified phase contrast (PC) sequence with motion sensitizing gradients was used. A piezoelectric oscillator [2] was applied to generate mechanical waves to be induced into the region of interest. The wave generation was synchronized to the motion sensitizing gradients (MSG). The mechnical excitation was performed with a frequency of 200 Hz and an amplitude of 600 µm. The oscillator was mechanically attached to the skin using an EKG-electrode.

The shear modulus was determined from the wavelength inside the tissue using multiple phase offsets and motion encodings in all three spatial directions. Phase images were acquired in slices with transversal, sagittal and coronal orientation. The total scan time was approximately 5 minutes per slice and motion encoding direction. Normal parameter settings for the modified PC sequence were TR/TE 100/24 ms, flip angle 40°, FOV 43 x 43 mm^2, slice thickness 0.34 mm, BW ±200 kHz. The in-plane matrix varied from 64 x 64 to 256 x 256. Three MSG cycles with an amplitude of 30 mT/m were applied. Image postprocessing was performed on a PC equipped with a Pentium4 1.9 GHz processor using Matlab (R13. The MathWorks, Natick, MA).

Results

The RF coil provided sufficient SNR for high-resolution in vivo imaging of healthy skin in human volunteers with microscopic resolution. The examination was tolerated by all volunteers with regards to examination time and positioning. With tissue density of 1000 kg/m^3, the determined average elasticity value, represented by the shear modulus, was 6.2 kPa , 7.5 kPa and 3.9 kPa for the skin, the subcutaneous fat and the veins, respectively.

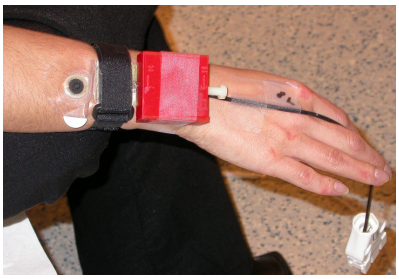

Fig. 1: The Coil was attached to the forearm, an EKG- electrode was connecting the skin with the oscillator lever.

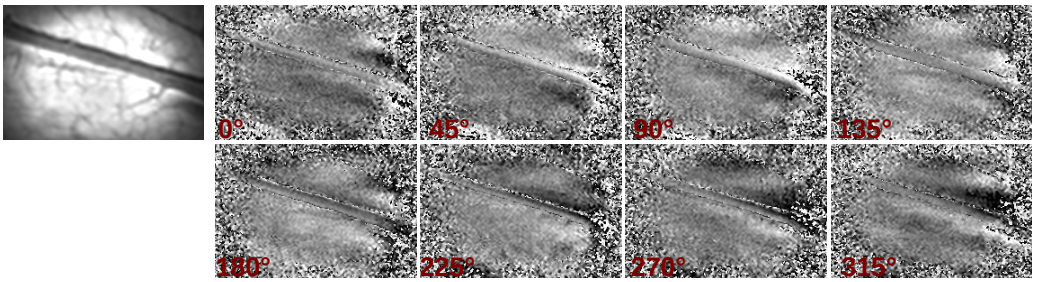

Fig. 2: Coronal magnitude image of subcutaneous fat and coresponding phase images with different phase offsets (0°-315° step size 45°). It is conspicuously that the wave propagates through tissue and vein.

Discussion

These results demonstrate that the combination of a modified phase contrast sequence and a dedicated surface-coil holds potential for high-resolution MRE of human skin. To achieve even higher SNR and spatial resolution, the use of 2- or 3-element phased array surface coils is desirable [3]. Furthermore, 3D acquisition schemes can potentially provide complete data of phase images with even higher SNR, however, this approach suffers from long scan times due to the acquisition of a larger k-space. Further investigations on volunteers and patients are necessary, to prove the feasability of the method for the characterization of melanoma, influence of aging, or the effects of skin cosmeticians.

References

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