In Vivo Examination of Skeletal Muscle with MR Elastography

K. Uffmann[1], S. Maderwald[1], S. Mateiescu[1], W. Ajaj[1], C. J. Galban[1], M. E. Ladd[1]
[1]Department of Diagnostic and Interventional Radiology, University Hospital Essen, Essen, Germany

Introduction

MR Elastography (MRE) is a non-invasive method for measuring the elasticity of human tissue. The feasibility of performing these measurements in skeletal muscle has already been demonstrated [1, 2]. For studying individual changes of muscle elasticity, repeated elasticity measurements in two healthy young volunteers were performed. Additionally various muscle groups in 12 healthy young volunteers were examined to head for establishing an elasticity database for muscle elasticity. In long term this database potentially can be helpful in evaluating if pathologies effecting skeletal muscle elasticity are detectable with MRE.

Methods

Mechanical waves were induced into the region of interest with a piezoelectric oscillator [3], and a phase-contrast MRI sequence synchronized to the oscillation was used to visualize the mechanical waves in the tissue. The shear modulus was determined from the wavelength inside the tissue using multiple phase offsets and motion encoding in the spatial direction parallel to the mechanical excitation. For the reconstruction of the image data it was assumed that the spatial phase changes represented transverse waves. The oscillator was coupled to a tendon attached to the muscle of interest. Frequencies of 142 Hz and 100 Hz were used for the upper and lower extremity muscles, respectively. The amplitudes were in the range of 600 to 700 µm. Coronal slices along the muscle were acquired in a total scan time of approximately 12 minutes per muscle group.


Fig. 1


Fig. 2


Fig. 3

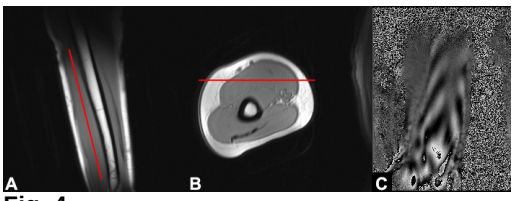

Fig. 4

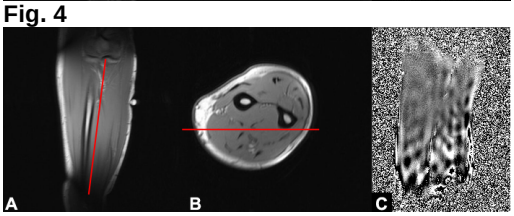

Fig. 5

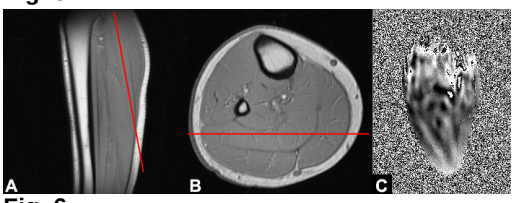

Fig. 6

Examinations of the biceps muscle in two subjects were repeated seven times within a time range of 8 months. Further measurements were performed on the biceps, soleus and gastrocnemius of 12 and in the flexor digitorum profundus of 4 healthy young volunteers using a 1.5T Siemens Sonata scanner. Fig. 1 – 3 show the setups and Fig. 4 – 6 acquired images of the examinations of the bisceps the forearm muscle, and the calf muscles, respectively. The solid lines in the subimages A) and B) show the orientation of the phase images shown in C).

Results

All volunteers tolerated the examination. The repeated examinations yielded a mean shear modulus of 13.3 ± 4.7 kPa for the first and 11.3 ± 1.7 kPa for the second volunteer. An average elasticity value, represented by the shear modulus, of 17.9 (± 5.5) kPa (biceps), 8.7 (± 2.8) kPa (flexor digitorum profundus), 12.5 (± 7.3) kPa (soleus), 9.9 (± 6.8) kPa (gastrocnemius) was determined.

Discussion

MRE was used in this study to provide baseline measurements of muscle elasticity in various muscle groups in healthy human subjects. As far as values of elasticity were published for the examined muscles [1, 2] the results of the presented study are consistent. To determine the efficacy of MRE as a viable diagnostic/prognostic method, diseased muscle tissue must be examined to compare its elasticity with the presently acquired data. Additionally, possible reasons for the variation of the muscle elasticity individually should be investigated more intensively to prove conditions for a higher reproducibility of the MRE examinations. It would also be of interest to examine the elasticity of muscles used for special tasks like calf muscles of sprinters or long distance runners To better evaluate muscle elasticity, other MRI measurements, such as muscle volume, diffusion and T2 relaxation, could be of value.

References

[1] Dresner et al., JMRI 13:296-2768 (2001)
[2] Basford et al., Arch Phys Med Rehabil 83, 1530 – 1536 (2002)
[3] Uffmann et al., Concepts of Magnetic Resonance (Magnetic Resonance Engineering) 15(4):239-254 (2002)