3D MR-Elastography of the Brain at 3Tesla

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Introduction

Brain diseases such as hydrocephalus are likely to alter the local viscoelastic properties of brain tissue. This fact is used in diffusion-weighted MRI of the brain. MR-Elastography, as a new non-invasive imaging technique to visualise and quantify viscoelastic properties of tissue [1,2], could provide information beyond what can be currently achieved and could provide new insight into diffuse pathological processes in the brain. The sponge-like architecture of brain tissue actually suggests that the viscosity might be of significant clinical interest since it is probing the water content. This study tests the feasibility of the technique for its application to in-vivo brain measurements within a clinical environment utilizing a 3T full-body scanner.

Methods

Generation of mechanical waves is performed by a transducer consisting of two coaxial coils mounted on the standard head-coil. The coils are driven by a signal generator which is triggered by the MR spectrometer (Philips Medical Systems). The coils are mechanically connected such that is it possible to either utilize a bit-bar for coupling the motion into the brain [3], or push against the skull from each side. A mechanical excitation frequency of 65Hz is used. The steady-state displacement fields are imaged in 3D by MRI using a motion-sensitized spin-echo sequence, which is phase-locked to the mechanical excitation. Reconstruction of the viscoelastic parameters is done utilizing a full 3D approach, which removes the contributions of the longitudinal wave by the application of the curl-operator [4].

Results

Mechanical waves are efficiently coupled into the brain and movies of coherent wave-propagation were acquired within healthy volunteers. The total amplitude of the wave field drops towards the ventricles as visible in Fig.1b). This is caused by viscose effects within the surrounding grey and white matter structures. The shear modulus map (Fig.1c) indicates that grey matter is stiffer than white matter and the latter stiffer that the central region. Average values of a collective of several individuals are shown in Fig.2a,b. The shear viscosity (Fig. 1d) drops towards the region of the ventricles. This is an expected feature, because the ventricles consist mainly of water, which does not attenuate the shear wave. If one assumes for simplicity that brain tissue is a bi-phasic material, it is only the solid matrix which can attenuate the shear wave. Fig. 2b) shows the average shear viscosity values within the three different regions, i.e. grey matter, white matter and ventricles.

Discussion

Initial testing and results suggest the technique is feasible. Quantised data set measurements of viscosity and elasticity from test subjects suggest grey matter is stiffer than white matter, and the new technique of wave propagation through the brain provides a more efficient method in order to extend the technique for further studies on hydrocephalic patients.

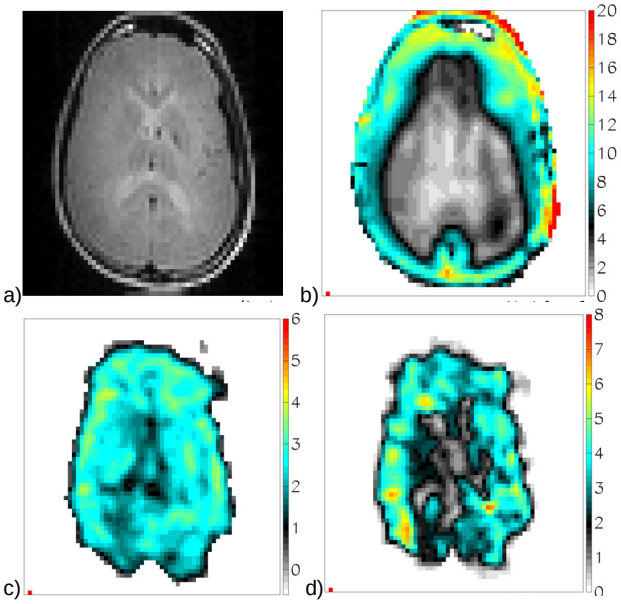

Fig.1: a) MR magnitude image of the brain of a healthy volunteer. b) Measured total displacement field in units of µm. c) Map of shear elasticity [kPa] and shear viscosity [Pa*sec].

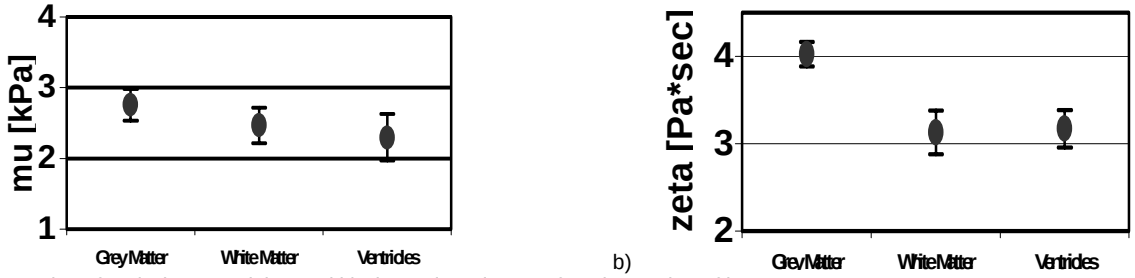

Fig.2: Average values for a) shear modulus and b) shear viscosity as a function region of interest.

[1] Muthupillai et al., 1995 Science 26 1854-7

[2] Muthupillai et al., 1996 Magn. Reson. Med. 36 266-74

[3] Kruse et al., ISMRM 1999, p 258.

[4] Sinkus et. al, MRI 2004 (in press)