Comparison of brain viscoelasticity and brain volumetry in healthy volunteers

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Introduction: Mechanical properties of human soft tissues can be investigated *in vivo* with dynamic magnetic resonance elastography (MRE) by applying low frequency shear waves and measuring the resulting tissue deflections [1]. From these data, elastic and viscoelastic modules are commonly calculated using the algebraic Helmholtz inversion [2,3].
So far, MRE is the only method for a noninvasive determination of the viscoelastic behavior of living brain tissue [4-7]. The brain's stiffness and internal friction can change significantly since some central nervous system pathologies are associated with a loss of brain volume [8-9]. To ensure an accurate differentiation and staging of such neurodegenerative diseases with MRE, the influence of changing but usually not in inversion algorithms included boundary conditions, e.g. the brain volume, has to be clarified. The objective of this study was therefore to investigate whether MRE based viscoelastic modules depend on atrophy related changes of the brain.

Methods: Experiments were run on a standard 1.5T clinical MRI scanner (Siemens, Erlangen, Germany). A custom-made head cradle was used for multifrequency head stimulation [10]. Four transverse image slices with through-plane motion-encoding direction were chosen in a central slab through the cerebrum. 32 time-resolved phase-difference wave images, $u(x,y,t)$ were Fourier-transformed for decomposition into complex wave images at driving frequency: $U(x,y,\omega)$, ($\omega / 2\pi$ = 25.0, 37.5, 50.0 and 62.5 Hz). Complex modulus images were obtained by wave inversion ($G(x,y,\omega) = -\rho\,\omega^2 U / \Delta U$) and spatially averaged. The resulting global modulus function was fitted by the springpot model $G = \kappa (i2\pi f)^{\alpha}$ with κ and α as variables. κ was transformed to a parameter related to shear elasticity μ taking η = 3.7 Pas as the mean viscosity of all volunteers derived by the three-parameter Zener model [10].
Volume data were acquired by a 3D Magnetized Prepared Rapid Gradient Echo (MPRAGE) sequence (TR/TE = 2110/4.4 milliseconds, TI 1100 ms, flip angle 15°, resolution 1 mm^3). Normalized volumes of the whole brain parenchyma were calculated using a method for total brain volume measurement (SIENAX software[11]) using the default BET options (Brain Extraction Tool; part of FSL4.0 Software Library; www.fmrib.ox.ac.uk/fsl) to extract the brain from the MR images.

Results: Results of the correlation analysis are shown in Fig.1. A good correlation (R = -0.78) was found for decreasing normalized brain volumes with increasing age. Combination of the viscoelastic modulus with the age showed a moderate correlation (R = -0.57) whereas the brain stiffness decreases with increasing age. No correlation (R = 0.19) was found between the normalized brain volume and the viscoelastic modulus determined by MRE.

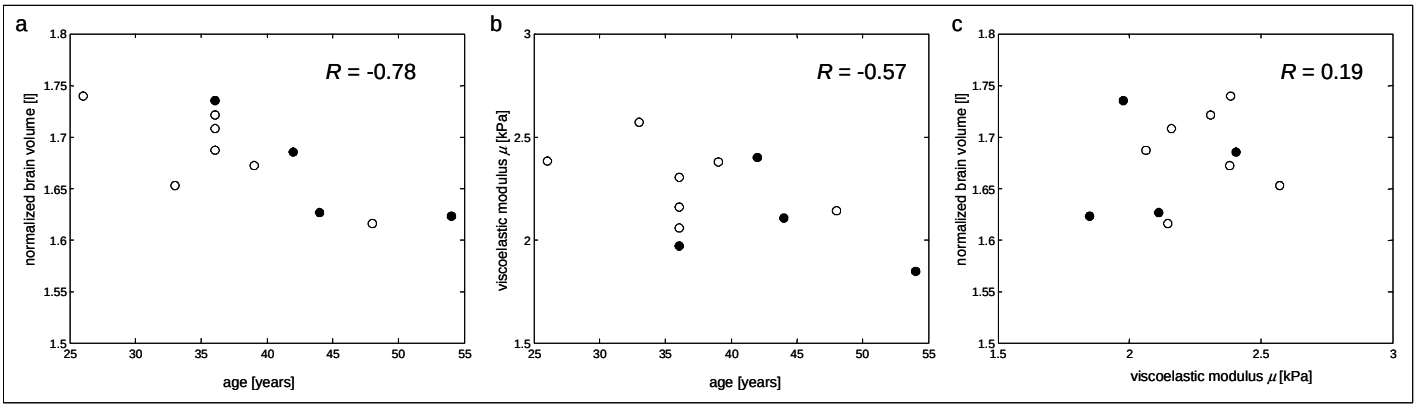

Figure 1: age dependencies of brain volume (a) and brain viscoelasticity according to the springpot model (b) and viscoelasticity versus volume (c) for healty volunteers (●:°females, ○: males). The correlation coefficients R are given in the graphs.

Discussion: Normalized brain volumes can be used as an index of atrophy. Although limited in the number of examined subjects, our study indicates the independence of brain viscoelasticity measured by MRE and atrophy. Ongoing studies are performed to improve the statistical significance of this conclusion. If our preliminary results are confirmed, brain MRE can be used as new diagnostic marker for neurodegenerative processes caused by various diseases.

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