Viscoelastic shear properties of the cerebellum and cerebrum measured by MR-Elastography

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Introduction

Brain disease or injury can dramatically alter the local viscoelastic properties of brain tissue. Lesions within the cerebellum in particular can lead to movement dysfunction and large masses can cause hydrocephalus due to restricted CSF flow. A technique to acquire the properties of healthy brain tissue and probe progressive changes could be useful to predict early onset of disease. The MR-Elastography [1, 2] technique was used to obtain in-vivo, healthy brain tissue properties of the cerebellum and compare with previously reported cerebral measurements [3-8].

Methods

A 1.5T full-body MRI scanner acquires high resolution T2 and MRE images. A transducer consisting of two coaxial coils is driven by a signal generator, mounted onto a standard head-coil and triggered by the MR spectrometer (Philips Medical Systems). The vibrations are transmitted to the brain using a bite-bar and personalised, moulded mouthguard for coupling. An excitation of 80Hz was used to optimise wave penetration while maintaining attenuation at a reasonable level. An optimised motion-sensitized, spin-echo sequence, including double motion encoding gradients is phase-locked to the mechanical excitation to image 3D steady-state displacements fields. A full 3D reconstruction of the viscoelastic parameters (complex-valued shear modulus) was applied with optimised filtering and application of the curl operator [9] to remove longitudinal wave contributions.

Results

High resolution brain images were obtained in the coronal plane to include both cerebral hemispheres and the cerebellum as shown in an example T2-weighted slice image in Fig 1a. An excitation frequency of 80 Hz transmitted waves to the brain tissue. Fig 1b shows an example displacement image in the s-direction at an arbitrary time point. Total mechanical wave amplitudes were in the range of 2 – 25 µm (Fig 1c) and resulted in wavelengths of 6 – 20 mm (Fig 1d). Storage (Gd) and loss (Gl) moduli maps (Fig 1e, f) were reconstructed and average storage moduli across all volunteers for grey (1.42 kPa) and white (1.34 kPa) matter in the cerebrum were measured. Storage moduli were also measured in the cerebellum for grey and white matter (1.10 kPa and 1.14 kPa) and were observed to be lower than in the cerebrum with only grey matter showing a significant difference (P=0.001).

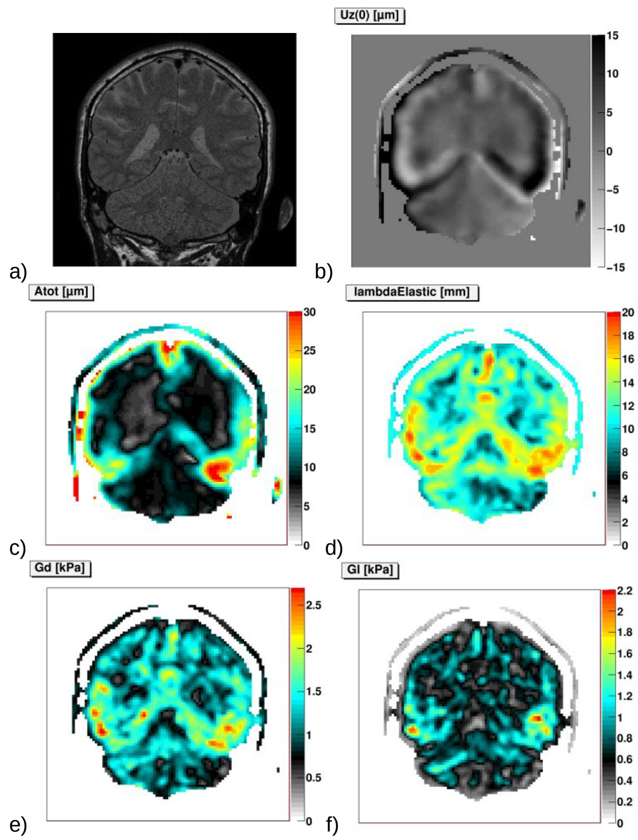

Fig.1: a) High resolution T2 image of the brain in coronal plane. b) Example displacement field at an arbitrary time point in the z-direction. c) Measured total displacement field in units of µm. d) Reconstructed image of wavelength of vibrations in units of mm. e) Reconstructed images of storage and f) loss moduli measured in kPa.

Discussion

MR Elastography images acquired in the coronal plane enabled measurements to be made in the left and right cerebral hemispheres and compare directly with measurements in the cerebellum. Viscoelastic properties of the cerebellum appear slightly lower than in the cerebrum with a significant difference appearing in grey matter. The latest high resolution brain MR-elastography images have resulted in lower viscoelastic measurements than previously reported possibly due to a different imaging plane compared to published data in the transverse orientation. The latest measurements also have a significant increase in phase stability of mechanical excitation due to individualized, moulded mouthguards. This, along with increased spatial resolution has revealed more structural details which may decrease measured values due to higher reflections.

References

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