High Resolution 3D Brain MR-Elastography

M. A. Green[1], R. Sinkus[2], L. E. Bilston[1,3]

[1]Prince of Wales Medical Research Institute, Sydney, New South Wales, Australia, [2]Laboratoire Ondes et Acoustique, ESPCI, Paris, France, [3]Faculty of Medicine, UNSW, Sydney, NSW, Australia

Introduction

Local viscoelastic properties of brain tissue are likely to be altered in brain disease or traumatic injury. MR-Elastography is a technique which can be used to probe these viscoelastic tissue properties [1, 2] in-vivo and the current study optimises several parameters, whilst maintaining good signal to noise in order to provide high resolution images of the healthy brain. Utilising a full body 3T full-body scanner within a clinical environment, imaging and reconstruction parameters such as excitation frequency, motion encoding gradients and mathematical filtering were optimised to enhance visualisation and spatial resolution.

Methods

Generation of mechanical waves are 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 to utilize a bite-bar for coupling the motion to the brain [3]. The mechanical excitation frequency of 90Hz has been chosen to optimise wave penetration whilst reducing attenuation. The steady-state displacement fields are imaged in 3D by MRI using an optimised motion-sensitized, spin-echo sequence, which includes two applied motion gradients which is phase-locked to the mechanical excitation. A full 3D reconstruction of the viscoelastic parameters using the Voigt Model is applied with optimised filtering and application of the curl operator to remove longitudinal wave contributions.

Results

High resolution brain images were obtained in the axial plane including the ventricles as shown in the T2 image in Fig. 1a. Optimising the excitation frequency and it's voltage to enable good mechanical wave penetration into the brain via the vibration bar was achieved at 90Hz. Fig 1b shows an example of the total amplitude in all imaging directions and the viscous nature of the brain causes the drop in intensity towards the centre. The very good correlation between the reconstructed elasticity and viscosity parameters with anatomical structures can be seen clearly in Figures 1c and 1d. The central region of the brain about the ventricles exhibits much lower elasticity (1.1kPa) that the surrounding white (2.1kPa) and grey (2.8kPa) regions. Viscosity too drops in this region (Ventricles: 0.6Pa s, white: 1.9Pa s, grey: 2.6Pa s) where shear waves are not attenuated and effective contributions by compressional waves have been correctly removed via the application of the curl operator [3]. This can be verified by taking a line profile through the curl of the displacement field in the z direction (Fig. 1e and 1f) which shows the level region towards the centre even though overall amplitude has not completely diminished.

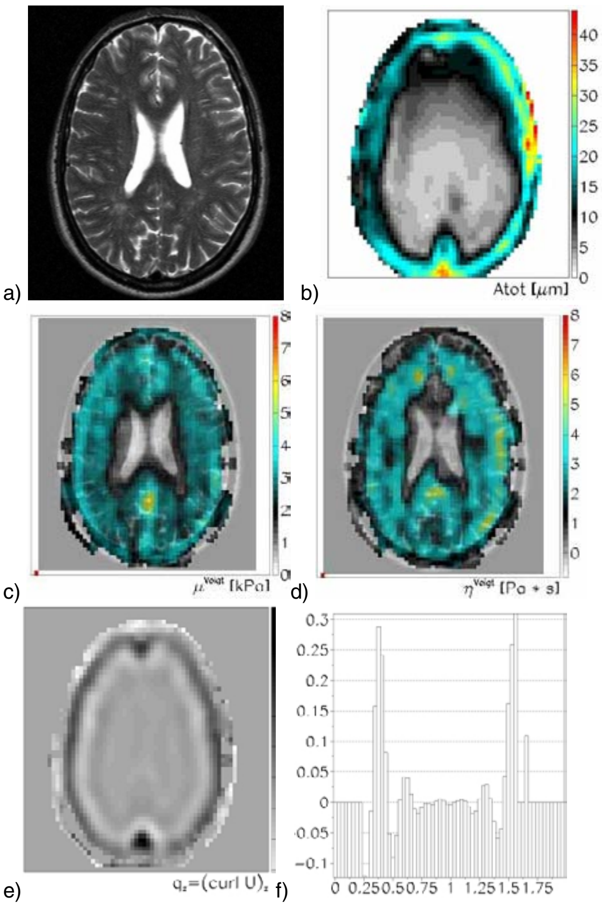

Fig.1: a) T2 image of the brain of a healthy volunteer. b) Measured total displacement field in units of μm. c) Map of shear elasticity [kPa] and d) shear viscosity [Pa*sec] overlaid with T2 anatomical image. e) Rotation in the z direction and f) a horizontal line profile.

Discussion

High resolution brain MR-elastography images have been achieved through parameter optimisation in both the MR-sequencing and reconstruction techniques. The reconstructed viscoelastic parameters have shown very good correlation with anatomical structures such as white/grey matter and ventricles towards the centre of the where CSF is prevailing. The quantified values of the viscoelastic parameters for the different regions agree well with rheological measurements [4-6] on bovine and porcine tissue.

References

1. Muthupillai, R. and R.L. Ehman, Nat Med, 1996. 2(5): 601-3.
2. Muthupillai, R., et al., Science, 1995. 269(5232): 1854-7.
3. Sinkus, R., et al., Mag. Res. Imaging, 2005. 23(2): 159-65.
4. Nicolle, S., et al., Biorheology, 2005. 42(3): 209-23.
5. Bilston, L.E., et al., Biorheology, 2001. 38(4): 335-45.
6. Kohandel, M., et al., Phys Med Biol, 2005. 50(12):2799-805.