Poroelastic MRE reconstructions of brain acquired with intrinsic activation

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Introduction:

Recently, magnetic resonance elastography (MRE) of the brain has shown significant promise. Strong results with MS have shown the potential of MRE in the brain[1,2]. One disadvantage is that eliciting shear waves deep in brain tissue is difficult because the skull and cerebral meninges form an excellent shock absorbing system that effectively isolates the brain from vibrations. Interestingly, the blood being pumped into the brain causes internal pulsations that can be used as a form of tissue actuation instead of external activation[3], termed "intrinsic activation". Intrinsic activation reduces the discomfort associated with the examination and should increase patient compliance.

MRE reconstructions of the brain and other tissues have primarily used assumptions of linear elasticity or viscoelasticity. However, there is evidence that brain is better described by a poroelastic model[4], which allows for an estimation of the shear modulus distribution as well as an estimate of pore pressure. Here, we present a study of three intrinsically activated brain studies.

Methods:

The acquisitions were phase-contrast gradient echo sequences with 2.5cm/sec motion sensitivity. The sequence was retrospectively gated for eight cardiac phases. Sixteen axial slices were acquired, with an acquisition time of eight minutes for each of the three directions resulting in a half hour total acquisition time. The tissue velocities calculated from the phase contrast sequence at each phase were Fourier transformed to fit the velocities to a sinusoid. The resulting sinusoid was the derivative of the motion. Each acquisition was processed onto a finite element mesh and the property distributions were estimated with both a linear elastic and poroelastic subzone-based iterative inversion algorithm.

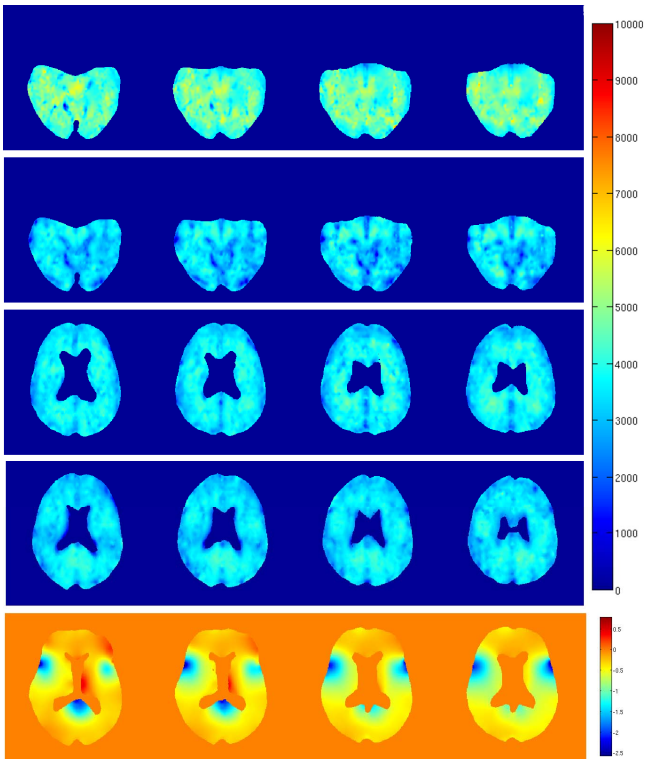

Figure 1 - Elastic reconstruction of shear modulus for brain A (row 1). Poroelastic estimate of shear modulus for brains A-C (rows 2-4). Pore-pressure distribution of brain B (row 5). All shear modulus estimates are in Pascals and pressure estimates are relative to atmospheric pressure.

Results:

Displacement data shows that the motion originates around the Circle of Willis and propagates out to the rest of the brain. The linear elastic estimate of the shear modulus (seen in Fig. 1, row 1) provides anatomical delineation of key features, such as the ventricles. However, the reconstructions lack symmetry and have some areas of much higher stiffness. The poroelastic estimations of shear modulus (seen in Fig. 1, rows 2-4) show better anatomical detail as well as superior symmetry. Also, the poroelastic volumetric estimates of brain stiffness are very consistent (3271.9 +/- 94.59 Pa, N=3). Poroelasticity also gives an estimate of the pore-pressure distribution (seen in Fig. 1, row 5).

Conclusions:

Intrinsic activation using the pulsation of the cardiac cycle is effective. Furthermore, poroelastic reconstructions supply a much less erratic estimate of the stiffness of tissue than a linear elastic estimate and, also, give consistent results amongst the three studies performed.

References:

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