MAGNETIC RESONANCE POROELASTOGRAPHY OF THE FELINE BRAIN

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Introduction

Magnetic resonance elastography (MRE) [1] is a quantitative physical examination focused on assessing the resistance to deformation or *stiffness* of tissue *in vivo*. MRE employs phase contrast MRI techniques to measure the displacement fields resulting from low amplitude, low frequency time-harmonic vibration. The mechanical property distributions associated with a given motion field are computed using 3-D model-based finite element reconstructions. Magnetic resonance poroelastography (MRPE) has been developed as an alternative to linear elasticity-based MR elastography techniques. The advantage of this approach is in its ability to model tissue comprised of two distinct phases, generally consisting of a porous elastic solid and penetrating fluid.

Methods

MRE image data were acquired for a series of six feline subjects at varying degrees of hydrocephaly resulting from induced ventricular obstruction using kaolin [2]. Multiple imaging sessions allowed for a controlled environment in which to investigate the effect of increased hydrostatic pressure on the mechanical response of brain tissue. Images were acquired pre-injection, three and six days post injection, and immediately following fluid drainage from a ventricular catheter (day 6). Time-harmonic mechanical excitation was imparted to the brain using a custom-built pneumatic actuator at a frequency of 85 Hz. The 3D time-harmonic displacement fields were measured with a motion sensitized spin-echo pulse sequence. The brain was modeled as a homogeneous poroelastic continuum. The shear modulus and pore-pressure amplitude distributions were computed using a reconstruction algorithm based on the equations of linear poroelasticity [3].

Results

The administration of kaolin as an inflammatory agent was successful in inducing mild hydrocephalus (Fig 1a). The shear modulus distribution provided in Fig 1b shows an elevated value observed in the white matter, which drops off sharply in proximity to the ventricles. This was expected, as the fluid with in the ventricles is unable to maintain a shear stress. Further, the pore-pressure amplitude distribution provided in Fig 1c shows a relatively uniform value across the brain. The average whole-brain shear modulus was found not to vary significantly with increased hydrostatic pressure as shown in Fig 2a. However, the average estimated pressure amplitude was found to roughly follow the changing ventricular volume (Fig 2b).

Discussion

Initial testing of poroelasticity-based MRE image reconstruction methods suggests this technique is capable of providing reasonable and consistent assessments of the elastic properties of the solid matrix in fluid-saturated media, including brain. This technique has been shown to provide estimates of the time-harmonic pore-pressure distribution across the feline brain, the magnitude of which was found to be associated with ventricular dilatation - a surrogate for increased intracranial pressure resulting from kaolin induced obstructive hydrocephalus. The average whole-brain shear modulus was found not to vary significantly with hydrostatic pressure, suggesting that no major macroscopic changes in tissue structure occurred across the brain within the timescale considered.

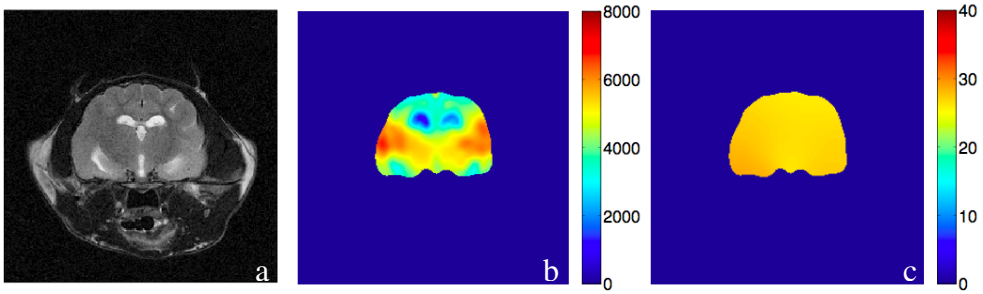

Figure 1: MRE magnitude image of a hydrocephalic feline brain (a). Shear modulus (b) and estimated pore-pressure amplitude (c) distributions computed using the poroelastic–based reconstruction algorithm. All values are given in units of [Pa].

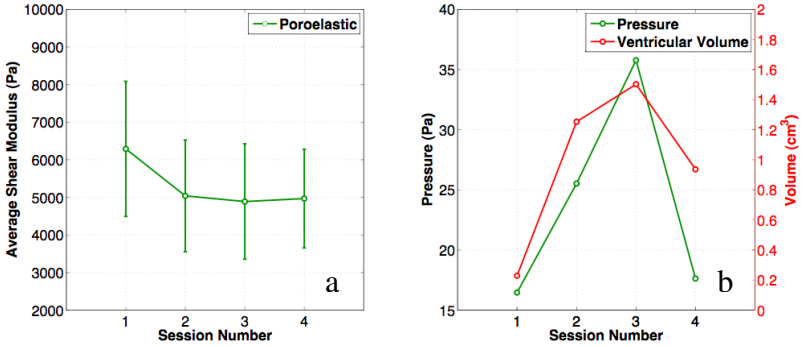

Figure 2: Average whole-brain shear modulus (a), ventricular volume, and average whole-brain pore-pressure amplitude for a representative animal at each imaging session.

References

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