

Feasibility study to measure changes in intracranial pressure using magnetic resonance poroelastography

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Background:

Changes in intracranial pressure (ICP) alter neurological function and can cause permanent brain damage if the change in ICP is sufficiently large. Measuring ICP noninvasively could lead to a more efficient way in diagnosing diseases such as hydrocephalus.

Introduction:

Hydrocephalus (HC) is a disease that is characterized by an increase in ICP. The normal transport of cerebrospinal fluid (CSF) is interrupted by either an obstruction in the lateral ventricles (non-communicating HC) or a lack of absorption of the CSF into the venous system (communicating HC). In non-communicating HC, the obstruction leads to an increase in ventricular size and an increase in pressure on the periventricular tissue. The current diagnostic standard is magnetic resonance imaging or computed tomography, however, these techniques only image an increase in ventricular size. HC could appear similarly to an *ex vacuo* change caused by cerebral atrophy or periventricular leukomalacia, where tissue loss occurs around the ventricles without an increase in pressure.

Magnetic resonance poroelastography (MRPE) is a very new concept in which the basics of linear poroelasticity are assumed (ie. biphasic continuum). An advantage to this method is that it allows for both a mechanical property measurement and an estimate of the pore-pressure distribution. Here, a feasibility study has been performed to measure the capabilities of this algorithm in measuring ICP.

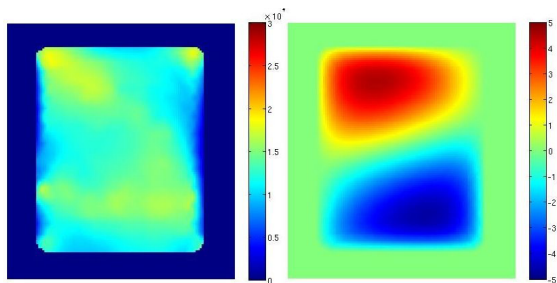


Figure 1 - Model-based reconstruction of the shear modulus (left) and the pore-pressure (right) distribution of a silken tofu phantom.

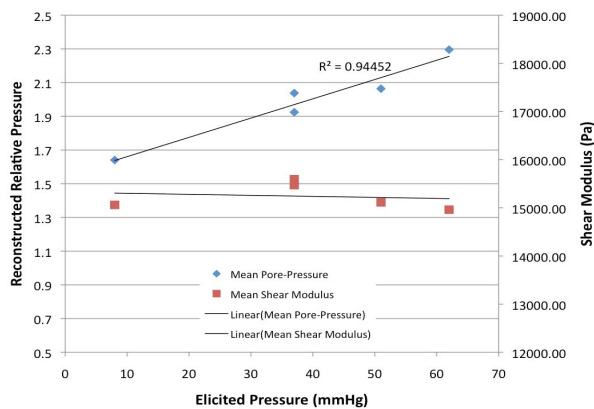


Figure 2 – Relative pressure (blue) and shear modulus (red) against the external pressure.

Methods:

A feasibility study was performed to mimic the reaction of brain tissue during HC. To model the tissue, silken tofu was used because it is known to be a poroelastic material. To reenact the onset of hydrocephalus, the tofu sample was placed in a sealed Plexiglas box that was lined with sponge. A vinyl tube was connected to the top of the box, which contained different levels of water and, thus, produced different external pressures. The box was coupled to a piezoelectric shear actuator and was vibrated at 100 Hz. An echo-planar phase-contrast sequence was taken at a range of external static pressures (8, 37, 37, 51, and 62mmHg) and the corresponding displacement data was reconstructed to estimate the shear modulus and pore-pressure distribution.

Results:

Figure 1 shows a shear modulus elastogram and a pore-pressure representation of the tofu phantom. The external pressure boundary conditions were real valued; therefore, the real-valued portion of the calculated pressure is shown since it is the component in-phase with these assumed conditions. The pore-pressure depicts a ‘mode shape’ of the phantom, with positive and negative pressure regions relative to the mean pressure. When the external pressure was altered, the calculated mean pore-pressure magnitude followed the same trend (blue dots in Figure 2). Importantly, the reconstructed shear modulus estimation stayed very consistent throughout each acquisition (red dots in Fig. 2), to within +/- 5%.

Conclusions:

The study showed the feasibility of measuring a change in ICP due to hydrocephalus using MRPE. Reconstructed average pressure followed the trend of applied pressures and the shear modulus estimation remained constant.

References:

1. Perrinez, et al. “Modeling of soft poroelastic tissue in time-harmonic MR elastography,” IEEE Transactions on Biomedical Engineering, 56, 598-608 (2009).