"Palpation of the Brain" Using Magnetic Resonance Elastography

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Introduction:

Physicians have long used palpation as an important diagnostic tool. While there is no clinical precedent for "brain palpation", it is possible that measurements of elastic properties might be useful for characterizing brain disease. In addition, such measurements are necessary prerequisites for finite element analysis studies of brain trauma and surgical simulation. Yet the available estimates of the shear modulus of brain tissue in the literature are inconsistent (Figure 1) and do not even agree on the relative stiffness of gray and white matter.

Magnetic Resonance Elastography (MRE) is a technique that allows the determination of the elastic modulus of tissue *in vivo*. This technique requires the application of acoustic waves to tissue, synchronous motion-sensitizing gradients to detect propagating acoustic waves and various algorithms to display the propagation of the waves and generate an elastic modulus map of the tissue of interest [1-3].

The goals of this technique are to obtain estimates of the elastic modulus of human cerebral tissue, to assess age dependence, and to study wave propagation in the brain.

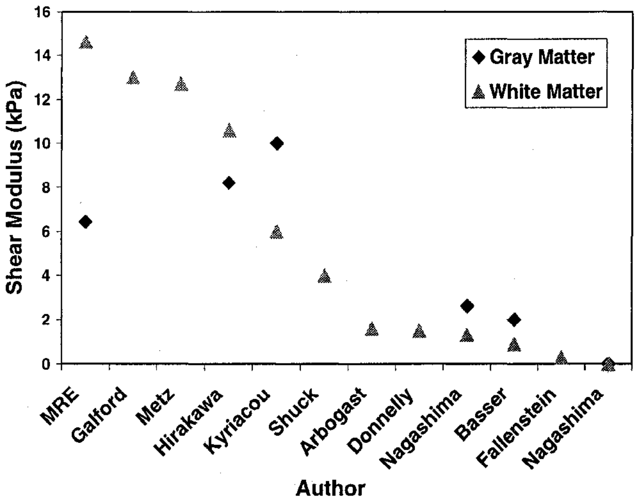

Figure 1. Brain Elasticity: Estimates in the Literature

Methods:

The MRE technique employs an electromechanical driver that vibrates the head with a maximum displacement of 50 microns to generate low amplitude shear waves [4]. The pulse sequence uses phase-locked gradients to image propagating waves with amplitudes as small as the wavelength of light. The wavelength varies according to the stiffness of the material and the input frequency. The wave image is processed to generate a quantitative local frequency estimate map (Figure 2).

Results:

Cerebral elastography studies were performed in 25 normal volunteers. The elastograms demonstrate that the shear modulus values of white matter are higher than that of gray matter. Figure 3 shows shear modulus measurements obtained from a group of eight volunteers. The mean shear modulus of cerebral white matter is 14.6 kPa, while the elasticity of gray matter is lower at 6.43 kPa. The difference is statistically significant. There is no discernable relationship between age and shear modulus.

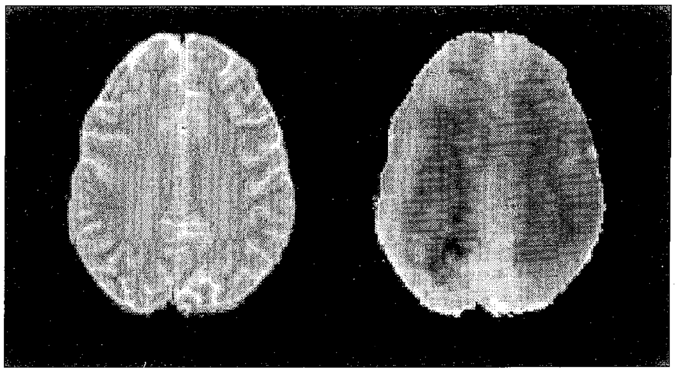

Figure 2. Left: T2 Weighted Spin Echo, Right: Local Frequency Estimate Map (Brain Compliance)

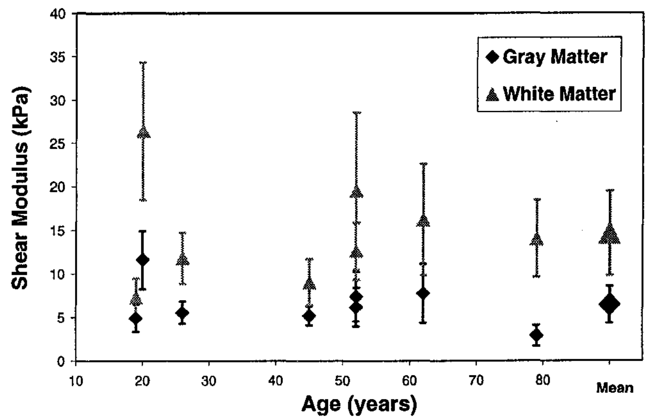

Figure 3. Elasticity Measurements of Cerebral Tissue *In Vivo*

Discussion:

These results are of interest because they are the first spatially resolved *in vivo* measurements of the elasticity of cerebral tissue. The estimates of brain elasticity in the literature, (Figure 1) were obtained *ex vivo*, from specimens without blood pressure and metabolic activity. This may explain why these estimates span several orders of magnitude and disagree on whether gray matter is softer or harder than white matter.

This study has shows quantitative measurements of the shear modulus of intracranial tissues are feasible with MRE. The results indicate that cerebral white matter is significantly stiffer than gray matter *in vivo* and that there is no apparent age trend in the adult population studied. We speculate that measurements of shear elasticity and other mechanical properties may offer useful new parameters for tissue characterization in neuroimaging.

References:

[1] Muthupillai R, et al., Proc. SMR, Nice, 189, 1995.

[2] Muthupillai R, et al., Science, 196, 1854, 1995.

[3] Muthupillai R, et al., Magn. Reson. Med., 36, 266, 1996.

[4] Felmlee JP, et al., Proc. ISMRM, Vancouver, 683, 1997.