Assessing the Mass Effect of Tumors on Adjacent Tissue: Initial Feasibility Study in a Phantom Model

K. Glaser[1], J. Pulido[2], and R. Ehman[1]

[1]Department of Radiology, Mayo Clinic, Rochester, MN, United States, [2]Department of Ophthalmology, Mayo Clinic, Rochester, MN, United States

Introduction:

The symptoms and deficits associated with brain tumors are often the result of mechanical influence or mass effect on adjacent functional brain tissue [1]. MR elastography (MRE) is a noninvasive technique that is designed to quantitatively assess mechanical properties of tissue, such as stiffness, in vivo [2]. In MRE, shear waves are introduced into tissue and the resulting displacement field is measured with a phase-contrast MRI technique and analyzed to measure the stiffness of the tissue. Given that the stiffness of mechanically loaded tissue increases in proportion to the amount of loading or stretching [3], our hypothesis is that MRE may be capable of imaging the acuity of the mass effect of an expanding lesion on surrounding tissue. Take, for example, the case of two lesions, one growing rapidly and one growing more slowly. The more slowly growing tumor will allow the surrounding brain tissue to relax and maintain uniform strain while the tumor continues to grow. The more rapidly growing tumor will not allow the surrounding tissue to relax, thus increasing the strain and the apparent stiffness of the tissue around the tumor. The hypothesis of this work was that MRE is capable of detecting stiffness changes due to the increased strain associated with increasing tumor volume in a phantom model.

Methods:

MRE data were collected in a 1.5 T GE Signa scanner (GE Medical Systems, Waukesha, WI) using a phantom of 10% bovine gel (B-gel) surrounding a 7-cm long latex balloon inflated in 5-mL increments up to 50 mL of air. MR magnitude images of the phantom are shown at the top of Fig. 1 (77 x 49 mm regions around the balloon). Images were acquired in a plane orthogonal to the long axis of the balloon. Shear waves were introduced into the phantom via a surface-mounted electromechanical actuator shearing in the slice-select direction. Continuous shear waves were produced at 100 Hz and imaged with a SE MRE sequence and 1 10-ms motion-encoding gradient pair at 1.76 G/cm oriented in the slice-select direction. The acquisition parameters included a 24-cm FOV, 128 x 128 prescribed acquisition matrix, 0.5 FOV acquisition in the phase-encoding direction, 32 contiguous 3-mm slices collected in 2 passes, TR/TE = 640/30 ms, 32 kHz bandwidth, and 4 time offsets. Stiffness estimates were performed with 20 3D directional filters [4] and a 5 x 5 x 5 direction inversion of the Helmholtz equation [5] and example elastograms are shown at the bottom of Fig. 1. 10-mm thick ROIs around the balloon (the red regions in the top row of Fig. 1) were created to sample the local stiffness estimates for each experiment and a boxplot of the stiffness estimates is shown in Fig. 2.

Results:

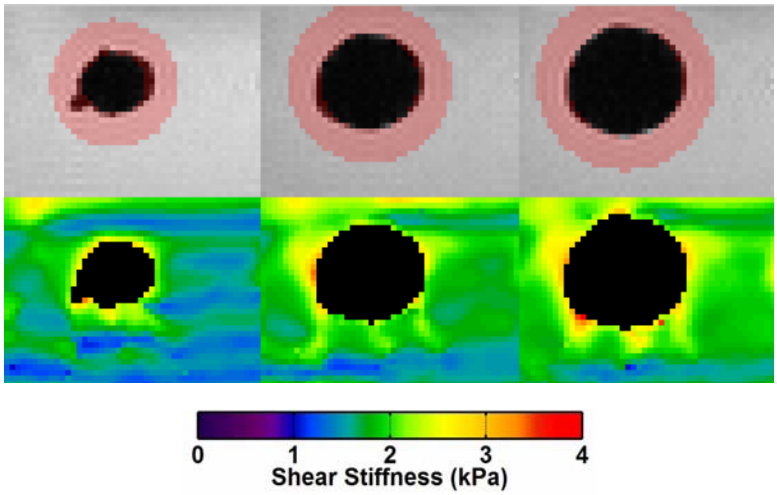

Figure 1: Magnitude images and elastograms with balloon volumes of 10, 35, and 50 mL. The red regions indicate the ROIs corresponding to the data shown in Fig. 2.

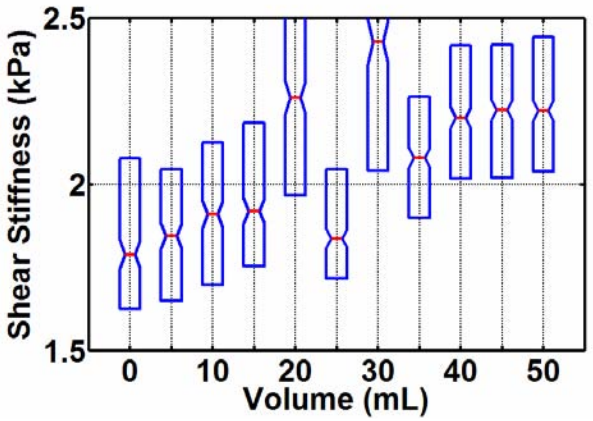

Figure 2: Boxplot showing the median and lower and upper quartiles of the stiffness data from each experiment in ROIs such as those indicated in Fig. 1.

Discussion:

These results demonstrate that MRE is sensitive to local changes in stiffness due to the increased strain in the gel produced by the increasing balloon volume. Future work will include extending this methodology to monitor local stiffness changes in in vitro and in vivo tissue. If similar behavior is observed in vivo, then MRE may become a useful tool for monitoring the progression of brain tumors and their response to treatment.

References:

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