MR Elastography of the Human Brain: Case Study Involving a Patient with a Temporal Glioma

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Synopsis:

The present study demonstrates the use of magnetic resonance elastography (MRE) for stiffness quantification in a patient with a brain tumor. The case involves a patient with a glioma in the left hemisphere. The elasticity was measured individually for the gray and white matter and the tumor. The tumor and the neighboring white matter in the left hemisphere contained the stiffest elasticity at 28.4 kPa and 24.2 kPa, respectively. White matter in the right hemisphere had an elasticity of 18.7 kPa. We conclude that MRE may be applicable for additional characterization of brain tumors beyond current MRI techniques.

Introduction:

MR Elastography (MRE) is a novel method for imaging tissue elasticity non-invasively. The feasibility of measuring the shear modulus of the human brain with MRE in vivo has already been demonstrated [1,2,3], which might allow for improved diagnosis or characterization of various brain diseases. Application of MRE for visualizing tumors in the breast [4,5] and the prostate [6] has shown tumor elasticity to be stiffer than the surrounding tissue. This study presents a first application of MRE for quantifying tumor elasticity in an in vivo brain. The case involves a 30 year old patient with a low-grade glioma in the left temporal lobe.

Methods and Materials:

All acquisitions were performed with a head coil on a 1.5 T scanner (Sonata, Siemens, Erlangen, Germany). For the MRE examination, the brain was excited by oscillating the skull at a frequency of 83.3 Hz via a bite bar attached to the lever of a piezoelectric actuator [3]. The lever displacement range was 600 µm. Phase images were acquired with a modified gradient echo sequence utilizing 3 cycles of motion-sensitizing gradients (MSG) with an amplitude of 30 mT/m. Acquisitions with the MSG oriented in the right left direction parallel to the lever motion were repeated for 8 phase offsets (0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°). The sequence parameters were: TR = 144 ms, TE = 39.2 ms, matrix 224x256, FOV = 224x256 mm^2, flip angle = 15°, and bandwidth = 260 Hz/pixel. The phase images with a slice thickness of 3 mm were oriented to maximize the cross sectional area of the tumor. The mean shear modulus was calculated from all phase offsets after applying a Local Frequency Estimation (LFE) [7] to each single phase image.

A stack of 18 high contrast T2-weighted images were acquired, so that one of these images coincided with the orientation, size and resolution of the MRE images. TR/TE were 5100/104 ms. These images were postprocessed with SPM (Wellcome Dept. Cognitive Neurology, London, UK) to generate segmentation maps for gray and white matter and the tumor tissue. Such maps contain probability values in each pixel, which are used for identifying the tissue type. A threshold of 80% was used to derive a binary mask for each of the three segmentations.

Diffusion tensor imaging (DTI) was used to determine white matter tract orientation in the presence of the tumor. T2-weighted images were acquired using a single-shot EPI sequence with the following parameters: TR/TE = 5300/85 ms, FOV = 256x256 mm^2, slice thickness = 3 mm and NEX = 4. These images again were oriented in the same way as the phase images. Diffusion gradients were applied along six directions with a b value of 750 s/mm^2. One additional image was acquired with a b value of 0 s/mm^2. The diffusion tensor was calculated at each pixel and then used for generating a directionally-encoded map that color codes neuron fiber orientation.

Results:

The tumor and surrounding edema could clearly be depicted in the high contrast T2 image (Fig. 1). Fig. 2 shows the mean shear modulus (elastogram) calculated from the phase images. The tumor location is designated by a region-of-interest (ROI: magenta), with the tumor mask being represented in Fig. 3A. The images in Fig. 3B and 3C are the segmentation maps of the white and gray matter, respectively. Red signifies pixels with a 100% probability that the tissue of interest is present. Evaluating the elastogram with the masks for the three tissue types for each hemisphere separately, it was found that the shear modulus of the gray matter was 16.4 kPa on the right side and 15.5 kPa on the left. The shear modulus of the white matter was 18.7 kPa in the right opposed to 24.2 kPa in the left hemisphere, where the glioma was located. The shear modulus of the tumor itself was determined to be 28.4 kPa. Fig. 4 shows the orientation of the neuron tracks along with the tumor ROI. The colors red, green, and blue represent fiber orientation in the right-left, anterior-posterior, and head-foot directions, respectively. The neuron tracks on the left hemisphere are displaced due to the glioma.

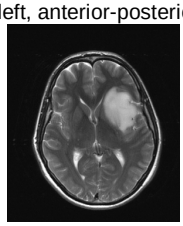

Fig. 1

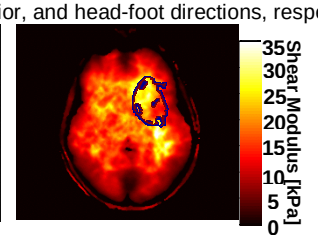

Fig. 2

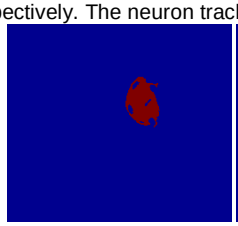

Fig. 3A

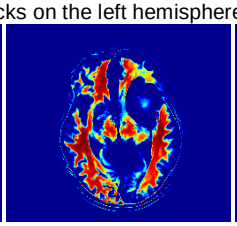

Fig. 3B

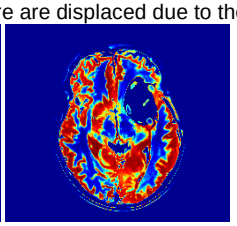

Fig. 3C

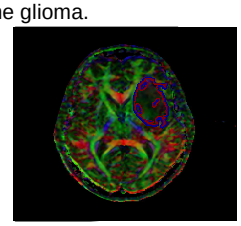

Fig. 4

Discussion:

Using the right hemisphere as a control, it can clearly be seen in the elastogram that the region in and around the glioma has a higher stiffness than the rest of the tissue in the brain. Our measurements for the white and gray matter are also in agreement with those from Kruse et al., where it was reported with MRE that gray matter was softer than white matter. Stiffer regions outside the tumor ROI appear to correlate with the displacement of neuron tracks. A possible explanation for the higher stiffness within the white matter of the left hemisphere could be the presence of additional stress imposed on the tracts by the expansion of the tumor.

Although the patient tolerated the MRE examination well, patient comfort remains an issue. Therefore, a shorter acquisition time by means of a faster imaging sequence would be desirable. A faster imaging sequence could also allow for the acquisition of multiple slices or even a 3D dataset. Further quantitative evaluation of the efficacy of MRE for diagnosis of brain tumors should include a thorough analysis of the effects of varying SNR on the reconstruction of the shear modulus. Additional improvement of the reconstruction algorithm used for the calculation of the elasticity from the MRE phase data would also provide more detailed information in the elastograms about the tissue.

References:

[1] Kruse et al., Proc. ISMRM 7 (1999), p. 258; **[2]** McCracken et al., Proc. ISMRM 11 (2003), p. 799; **[3]** Uffmann et al., Proc. ISMRM 11 (2004), p. 1768; **[4]** Sinkus et al., Phys Med Biol. (2000), 45:p.1649; **[5]** McKnight et al. AJR (2002), 178:p.1411; **[6]** Sinkus et al., Proc. ISMRM 11 (2003), p.586; **[7]** Manduca et al., SPIE 1996;2710:616-623.

Acknowledgments:

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