Measurement of the Vitreous Humour Deformation and Strain with Tagged MR Imaging

Ming Li[1,2], Paul Gamlin[3], Mark S. Bolding[4,5], Ronald J. Beyers[1], Nouha Salibi[1,6], Xiaoxia Zhang[1,2], and Thomas S. Denney Jr. [1,2]

[1]*Auburn University MRI Research Center, Auburn University, Auburn, AL, United States*, [2]*Electrical and Computer Engineering, Auburn University, Auburn, AL, United States*, [3]*Department of Ophthalmology, University of Alabama at Birmingham, Birmingham, AL, United States*, [4]*Departments of Radiology, Vision Sciences, and Neurobiology, University of Alabama at Birmingham, Birmingham, AL, United States*, [5]*Civitan Functional Neuroimaging Laboratory, University of Alabama at Birmingham, Birmingham, AL, United States*, [6]*MR R&D, Siemens Healthcare, Malvern, PA, United States*

TARGET AUDIENCE: Ophthalmology specialist, scientist and engineers with research interest of vitreous humour

PURPOSE: The vitreous humor is a collagenous gel inside the eye globe. The vitreous is thought to liquefy with age and changes in viscosity are thought to be associated with a range of pathologies including retinal detachment. The dynamics of the vitreous humor under controlled eye movements is difficult to study in vivo. Previous work [1] used tagged MRI and a custom-built eye coil to study vitreal motion in response to smooth pursuit eye movements, but the analysis assumed that the globe is spherical and the vitreous humour is a homogeneous fluid [2]. However, the lens can cause a distortion in the spherical geometry of the globe and the vitreous humour is known to be heterogeneous. In this abstract, we present a method for imaging the deformation of the vitreous humor with a standard head coil in a 7 Tesla scanner and a post-processing technique that can measure regional shear strain in the vitreous humor without assumptions about the geometry of the globe or material properties of the vitreous.

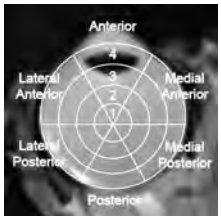

Fig 1. Vitreous sectors for regional shear strain analysis.

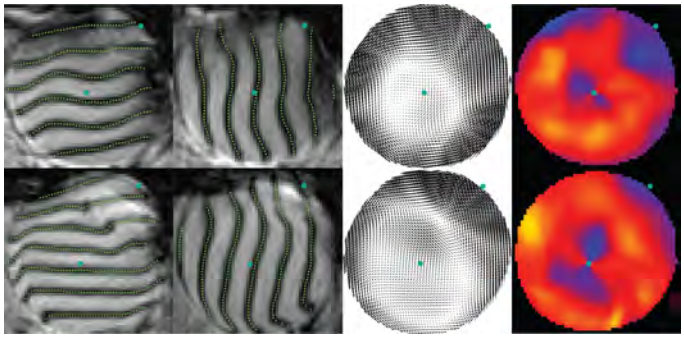

Fig 2. Horizontal (left) and vertical (middle left) tracked tag points, dense deformation fields (middle right) and shear strains (right) ranging from blue (-10%) to yellow (30%) for volunteers aged 23 years (top) and 46 years (bottom). Cyan dots near centroid are the rotation centers used to compute shear strains, and dots near boundary denote the center of the cornea.

METHODS: 5 normal volunteers with ages from 20 to 54 were imaged in a Magnetom 7T scanner (Siemens Healthcare, Erlangen, Germany) while undergoing a smooth pursuit eye movement generated by the volunteer tracking a target with a sinusoidal motion from left to right with an amplitude of ±6.8° and a period of 2000ms. The display of the moving target began with a trigger sent to the MRI scanner to start acquisition.

Imaging Protocol: An MPRAGE anatomical scan was acquired first with no eye motion for the purpose of subsequent motion slice planning. Tagged image planes were approximately transverse, but were slightly oblique to align the planes parallel to the right lateral rectus muscle (RLR) and with the rotation plane of the eye globe. Tagged images were acquired in a double-oblique transverse plane with a standard cardiac, prospectively gated, gradient-echo sequence using a 32-channel head coil (Nova Medical, Boston, Mass.). Two tagged acquisitions with 4mm spacing were performed for each motion with tags oriented perpendicular to the RLR in one acquisition and parallel to the RLR in the other. Scanning parameters were 0.44x0.44mm^2 in-plane resolution, 1.5mm slice thickness, TR/TE: 8.5ms/4.0ms, flip angle: 10°, 302 Hz/pixel. 7 segments were acquired per phase for a temporal resolution of 59ms.

Deformation measurement: A tag tracking method developed for cardiac tagged MRI analysis was adopted. Gabor filter bank was used to extract tag points along tag lines by detecting edge information from the angle map. Each tag point was classified to one of the reference tag lines by using a discrete optimization algorithm in order to compute its displacement. Since the detected tag points had only pixel-wise accuracy, their positions were further refined with an active contour based method [3], followed by manual inspection and modification, if necessary. A dense 2D displacement field was fit to the deformed tag lines in each time frame using the discrete model-free method [4]. Strain was computed and averaged over the 4 radial layers and 6 circumferential sectors shown in Fig 1.

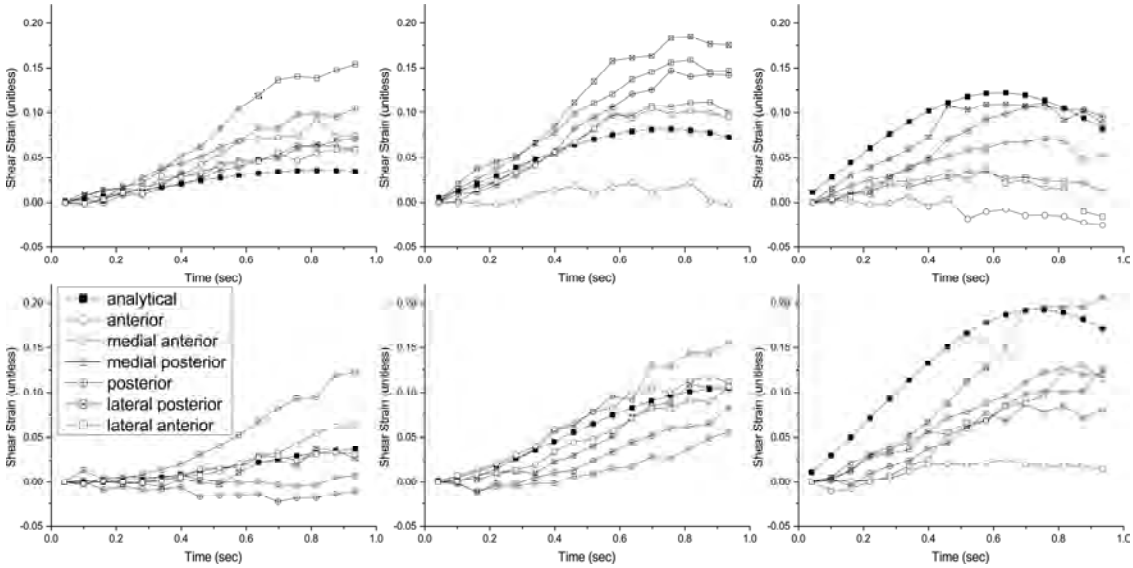

Fig 3. Shear strains versus time for each of the six regions at layer 2 (left), layer 3 (middle) and layer 4 (right) in a volunteer aged 23 years (top) and 46 years (bottom). Shear strains from the analytical model in [2] are shown with black square symbol.

RESULTS and DISCUSSION: Figs 2 and 3 show results from a 23y and 46y volunteers. Note the variability in shear strain with sectors and with respect to the analytical model, which assumed that the vitreous humour is a homogeneous fluid. Peak shear strain in the medial anterior sector at layer 2 was correlated with the age (-0.92, p=0.027). All other parameters and sectors including viscosity parameters calculated from the analytical model were not significantly correlated.

CONCLUSION: The proposed technique can measure regional shear strains in the vitreous humor in vivo and may be more sensitive to changes in the vitreous than analytical methods.

REFERENCE: [1] Piccirelli, et al. NMR in Biomed. 2011; [2] David, et al. Phys. Med. Biol. 1998; [3] Denney, IEEE TMI 1999; [4] Denney and McVeigh, JMRI 1997