IMPROVEMENTS IN SHEAR MODULUS RECONSTRUCTION IN-VIVO BREAST DATA USING A VISCOELASITC MATERIAL MODEL IN OPTIMIZATION DRIVEN MR ELASTOGRAPHY

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INTRODUCTION A linear elastic material model is commonly used in MR Elastography; nevertheless the structural and material complexity of soft tissue makes it more suitable for more complex material models, especially in the case of breast tissue. Various studies have successfully estimated the mechanical properties of breast tissue *in vivo* using a linear elastic model [1-3]. However, more recently viscoelastic properties have been observed inside breast lesions [4-6]. Moreover, it has been shown that a linear elastic model based reconstruction algorithm can lead to poor and misleading characterizations of viscoelastic data [7]. This work demonstrates the inadequacy of a purely elastic MRE reconstruction for clinical breast data and shows promising results using a viscoelastic model.

DATA AND METHODS Three subjects (12 studies) from a clinical database collected from breast cancer patients who volunteered for the MRE exam procedure and that followed their clinical progression were used. Data was collected using a Philips Achieva 3T scanner and a pneumatic actuator induced 3D motion within the breast (frequency 100Hz). A 2D phase-contrast spin-echo echo-planar MR pulse sequence was used. Motion-encoding gradients were synchronized with the mechanical excitation and eight different phase offsets were used to characterize the harmonic motion. Seven slices (2mm thick) were acquired with a 64x64 in-plane resolution. The measured 3D harmonic motions were processed into complex motion amplitudes, $\vec{U}(\vec{x})$, such that the harmonic behavior of the tissue is given by $\vec{u}(\vec{x},t) = \mathrm{Re}\{\vec{U}(\vec{x})e^{i\omega t}\}$. The underlying material property distribution was estimated using a finite element-based optimization framework, where the difference between the measured motion amplitude, $\vec{U}_m$, and the calculated motion amplitude, $\vec{U}_c(\theta)$, was minimized by updating the material properties, θ. The calculated motions were generated using a mesh with 27 node quadratic hexahedral finite elements, where each nodal point corresponds to an MR voxel. The viscoelastic model was implemented by reconstructing nodally varying complex shear moduli, whereas the linear elastic model reconstructs purely real-valued shear moduli. A subzone method [3] was used to give a typical run time of 4 hours using 8 processors.

RESULTS The results for the three subjects considered show that linear elastic MR reconstructions were inadequate for breast data. Figure 1 shows a comparison between the results obtained using the viscoelastic versus the elastic material model for one of the patients considered, at an early stage of her treatment. A contrast enhanced image clearly shows the outline of the malignancy. Shear modulus reconstruction using a linear elastic model does not clearly delineate the tumor from the background healthy tissue, whereas the reconstruction using a viscoelastic model highlights a region of increased stiffness corresponding to the location of the tumor.

CONCLUSIONS The linear elastic reconstructions of *in vivo* breast data were shown to be inadequate. Tissue behavior has a significant viscoelastic component; neglecting it increases the model data mismatch which in turn leads to inaccurate reconstructions. In turn, the viscoelastic model reconstructions lead to correct location of abnormal tissue in all cases considered and prove to be an adequate tool for monitoring the clinical progression of the treatment.

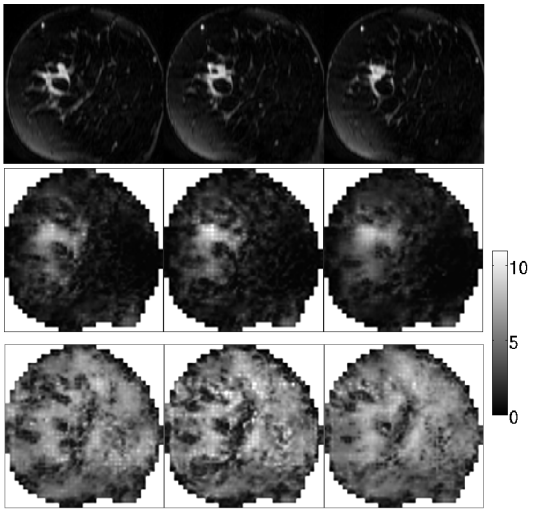

Figure 1: Contrast enhanced MR magnitude images (top, white arrows indicate tumor location) and shear stiffness distributions [kPa] of in-vivo breast data using a viscoelastic material model (middle), and an elastic model (bottom).

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