Abstract A soft tissue elasticity measurement technique based on Magnetic Resonance Elastography (MRE) is presented. In this technique, a tissue specimen is encased in gelatine-agar block with known elasticity modulus. This block is slowly compressed using a MRI compatible device and displacements are measured using a phase contrast MRI technique. These displacements are processed using an iterative MRE model and the tissue elasticity modulus is obtained. This technique was validated with chicken breast tissue, the elasticity modulus of which was measured independently using a conventional method and a good agreement was achieved.

Introduction Many biomedical applications require knowledge of elasticity data of soft tissues. In medical imaging, some researchers have attempted to model soft tissue deformation in the brain and the breast for intraoperative image guidance [1] and image coregistration [2]. The precision of the predicted deformation is highly dependent on the accuracy of elasticity data implemented in the model. Elastography is another application where elasticity can serve as a contrast mechanism to detect tumors of the breast and prostate. The latter can be used as an effective diagnostic technique where the tissue specimen to the gelatine-agar, the displacement data is processed using the MRE technique described in [5]. This technique is iterative and consists of stress calculation followed by elasticity modulus updating.

Methods This technique is based on the constrained MRE technique described in [5]. First a piece of tissue is dissected and encased in a block of 4% gelatine and 0.5% agar mixture. Encasing the tissue sample takes place while the mixture is solidified to prevent any damage or alteration to the tissue elasticity while the mixture is still liquid. After solidifying, a small block of this mixture, which was casted inside a birdcage coil to achieve high SNR.

Prior to compression, MRI image of the block is acquired for Finite Element (FE) modeling. The block is, then, compressed and displacements measured using a STEAM sequence. To obtain the elasticity ratio of the tissue sample to the gelatine-agar, the displacement data is processed using the MRE technique described in [5].

Results A piece of chicken breast tissue was carefully dissected into a 15 × 15 × 10 mm block. The Young’s modulus of this block was, first, measured using an indentation technique similar to Erkamp et al. 1998 [3] resulting in 7.55 kPa. This tissue was encased in a 30 × 40 mm gelatine-agar block as described above. Prior to the MRE experiment, the encased tissue was placed inside the birdcage coil, slightly preloaded, and advanced inside the bore of a GE SIGNA 1.5 Tesla scanner. Sagittal MRI image of the block was acquired using a 2-D spin-echo sequence with TR/TE = 300/14 ms and FOV = 40 mm. The block, then, underwent a sinusoidal compression of 1 Hz and a 2.3 mm amplitude. A STEAM pulse sequence with TR/TE = 950/12 ms and a mixing time $T_{M}$ of 500 ms was used to acquire the displacement data of a central plane shown in Figure 2. Starting with Young’s modulus ratio obtained from the measured strain images, as shown in Figure 2, convergence was achieved after 3 iterations. The final reconstructed modulus 6.73 indicates that there is an error of 10.9%.

Conclusions This article presents a novel method to measure soft tissue elasticity modulus using a MRE technique [5]. With this method, it is possible to measure elasticity modulus of a soft tissue specimen with an arbitrary size and shape. Unlike traditional methods [3,4] which involve tiny force measurement, this method involves the measurement of one displacement component of a plane through a soft block encasing the tissue. Results obtained from this technique is encouraging and indicate that it can be used as an effective way for elasticity measurement of breast tissues. Using this technique, we will measure elasticity modulus of normal and abnormal breast tissue specimens with known histological results.

References

Figure 1: MRE compression apparatus. This apparatus applies a quasi-static sinusoidal compression to a soft block encasing the tissue and placed inside a birdcage coil to achieve high SNR.

Figure 2: a) Sagittal image of encased chicken breast tissue. b) corresponding measured strain c) MRE results where the dashed line represents the independently measured tissue’s Young’s modulus.