

# Palpating Breast Cancer by Magnetic Resonance Elastography

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## Introduction

Breast palpation is an important screening tool for breast cancer. Approximately one third of breast cancers in some series are detected only by palpation and not by mammography [1]. Unfortunately, many lesions are too small or too deep to detect early by physical exam. Because tumors are usually much stiffer than normal surrounding tissue, changes in tissue elasticity have been shown to be a sensitive indicator of pathology [2]. Available conventional imaging modalities can not directly measure these mechanical properties, thus providing motivation for the development of alternative imaging techniques.

Previously we described a technique using magnetic resonance imaging to visualize propagating acoustic shear waves, allowing for the quantification of the elastic properties of tissues [3,4]. Previous work in normal breast volunteers has shown that this technique, called magnetic resonance elastography (MRE), is feasible *in-vivo* and is capable of evaluating the elastic properties of normal fatty and glandular breast tissue [5]. The objective of this work is 1) to determine if MRE is capable of delineating known breast cancer tissue from normal tissues *in-vivo*, and 2) to quantify the shear modulus of various breast cancers *in-vivo*.

## Methods

In seven patients with known breast cancer, we applied our 2D gradient echo pulse sequence triggered to an electromechanical driver to image cyclic motions caused by propagating acoustic shear waves [3,4]. A newly designed breast coil was built to increase wave penetration by applying lateral compression and shear motion in the superior-inferior direction to both sides of the breast simultaneously. The electromechanical driver used delivers low amplitude shear waves in the range of 75-200 Hz.

Patients were placed in the prone position in a 1.5T whole body imager. We localized tumors in the axial plane using standard spin echo T1 and T2 weighted images. We then isolated a particular slice for elastography. The malignant tumors ranged in size from 1 cm –10 cm.

The propagating shear waves were imaged in the axial plane, with motion sensitization in the superior-inferior direction. Six different time offsets were used between the shear motion and the motion gradients, which allows for temporal information of the propagating waves.

The resulting wave images were processed using a time filtered local frequency estimator algorithm [6] to obtain shear modulus maps. To calculate shear modulus ( $\mu$ ) we used a Voight model [7]:  $\mu = \lambda^2 f^2 \rho$  where  $\lambda$  is the local wavelength,  $f$  is the applied frequency of vibration, and  $\rho$  is the density of the breast tissue.

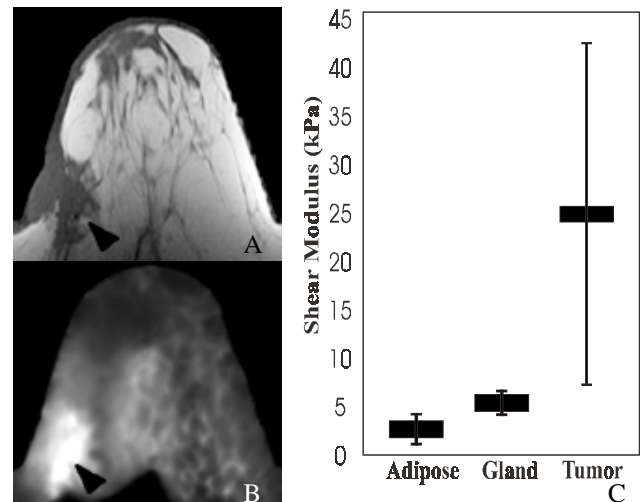
## Results

Breast size, consistency, and the amount of compression affected the optimal frequencies for each patient. Because attenuation is greatest in large fatty breasts, lower frequencies (75-100hz) were necessary to achieve complete penetration. At 200 hz complete penetration was achieved in only one patient. In this patient, the breast was almost completely occupied by tumor.

Areas of increased stiffness on the elastograms of each of the seven patients were found and correlated well with the tumors on the T1- and T2-weighted images [Fig. 1]. Heterogeneity within some tumors was obvious on several elastograms and one patient clearly had evidence of tumor heterogeneity on the standard spin echoes. The necrotic and cystic areas within that breast showed

as softer areas surrounded by the stiffer tumor on the elastogram [Fig. 2].

The tumor shear modulus values calculated showed a frequency dispersion (increasing as frequency increased) and a wide range of values at each frequency. Figure 1c shows the average shear modulus values at 100hz for tumors compared to normal fatty and glandular tissue.



**Figure 1.** A) T1W SE image of a patient showing a 4 cm tumor (arrow). B) Corresponding elastogram showing stiffest tissue in region of tumor. C) Average shear modulus values of normal adipose and glandular tissues compared with tumor tissues.

## Discussion

Magnetic resonance elastography identified the tumors in all seven patients. The shear modulus values in these tumors were consistently higher than surrounding normal tissues. We conclude that MRE remains worthy of further investigation as a viable imaging technique for breast cancer screening. Propagating shear waves can be generated through the breast *in vivo* and the elastic properties of the tissues can be calculated. To date, we have used a 2D acquisition technique and a rudimentary 2D process for analysis. Despite these limitations, we can obtain good contrast between tumors and normal surrounding tissue. As propagation patterns are very complex in heterogenous tissues such as the breast [3], we are continuing to develop 3D imaging and processing methods for more accurate characterization of normal and abnormal breast tissues.

## References

- [1]Chapuis L, et al, *Helv. Chir. Acta*, 55, 895, 1989.
- [2]Sarvazyan A, *J. Acoust. Soc. Am.*, 93, 2329, 1993.
- [3]Muthupillai R, et al, *Science*, 296, 1854, 1995.
- [4]Muthupillai R, et al, *Magn. Res. Med.*, 36, 266, 1998.
- [5]Lawrence A, et al, *ISMRM*, Sydney, 233, 1998
- [6]Manduca A, et al, *Proc. SMR*, Vancouver, 1905, 1997
- [7]Yamakoshi Y, et al, *IEEE Trans. Ultrason.* 37, 45, 1990