

## Noncompressive MR Elastography of Breasts

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**Introduction:** A woman born in the United States today has a 1 in 8 chance of having invasive breast cancer during her lifetime<sup>1</sup>. An estimated 39,970 breast cancer deaths (39,520 women, 450 men) were expected in 2011. Death rates for breast cancer have steadily decreased in women since 1990, which represents progress in both earlier detection and improved treatment<sup>2</sup>. Early diagnosis of breast cancer is critical, because treatment is most effective at the early stages of the disease. However, mammography, the principle tool for diagnosing breast cancer, has radiation exposure risks and is significantly less accurate in young women with mammographically dense breast tissue; women who also have a higher risk of developing breast cancer than women with less dense breast tissue<sup>3</sup>. Other techniques, like ultrasound and contrast-enhanced MRI, have low specificity for breast cancer. In recent years there has been interest in exploring the potential of MR elastography as a method to augment the diagnostic specificity of breast MRI<sup>4-6</sup>. In past implementations of breast MRE the required mechanical drivers have been placed in direct contact and to some extent compressing the breast. However, a recent human study has shown that compression can affect the mechanical properties of normal and diseased breast tissues<sup>7</sup>. This may explain the inconsistencies in the reported stiffness values of breast tissues from different elastography methods in the literature<sup>4-7</sup>. We have developed and tested a new breast MRE technique that does not require any tissue compression to avoid its possible effect on breast tissue stiffness<sup>8</sup>. In this study, we further improved the noncompressive breast MRE technique with a more efficient breast MRE driver and a shorter MRE volumetric imaging sequence. **Our purpose** was to design the technique to be comfortable for the patients and capable of producing volumetric elastograms of both breasts simultaneously. **Target audience** includes clinicians and scientists interested in new technologies for MRI-based breast cancer imaging.

**Methods:** (1) **Noncompressive Breast Driver:** The noncompressive breast MRE driver was designed to be narrower than the previous design (2 x 0.6 x 22 cm vs. 3.5 x 0.8 x 20 cm, width x thickness x length)<sup>8</sup>, which increased the efficiency of the driver due to its decreased volume. Our study was approved by our Institutional Review Board (IRB). Subjects were scanned in the prone position, feet first, in a 1.5 T MRI scanner (GE, Signa, Wisconsin, USA). The MRE driver was positioned in between the sternum and the bridge of a commercial breast RF coil (Liberty 9000 8-ch. breast coil, USA Instruments, Inc., Aurora, OH). (2) **MRE Imaging Sequence:** Imaging was performed with a 3D GRE MRE sequence similar to one previously reported<sup>8</sup>. The parameters included vibration frequency = 40 Hz; FOV<sub>xy/z</sub> = 30-34/30-34/14.4-18 cm; 4 phase offsets; motion-encoding gradient (MEG) amplitude = 2.8 G/cm; TR = 31.3 ms; TE = 27.2 ms (fat/water in-phase echo time); flip angle = 15°; BW = 31.25 kHz; axial imaging plane covering both breasts in the SI direction; acquisition matrix = 96X96X40; reconstruction matrix = 256X256X36; NEX = 1; SENSE acceleration factor = 2 (RL direction); total scan time = 9'54" (free breathing). (3) **Calculation of Elastograms:** The vector curl of the measured wave data was calculated using 3x3x3 derivative kernels on the wrapped phase data acquired in three orthogonal directions<sup>9</sup>. A 3D local frequency estimation (LFE) inversion was performed on the curl data with 2D directional filters (cut-off frequencies of 2 and 128 cycles/FOV) to calculate the volumetric elastograms of the two breasts<sup>10</sup>.

Regions of interest were drawn in the adipose and glandular tissue of all subjects and in the tumor for the patient volunteer to measure the stiffness of the tissues.

**Results:** Seven volunteers without known breast diseases and a 41-year-old female patient with a biopsy-proven invasive ductal carcinoma were enrolled in this preliminary study. The results are shown in Fig. 1. In the seven normal volunteers, the stiffness of adipose tissue ranged from 0.25 to 0.41 (mean = 0.33) kPa and glandular tissue ranged from 0.46 to 0.9 (mean = 0.64) kPa. For the patient, the stiffness of adipose tissue was 0.41 ± 0.1 kPa, glandular tissue was 0.90 ± 0.18 kPa and the invasive ductal carcinoma was 1.42 ± 0.17 kPa. Fig. 2 shows images of the patient with invasive ductal carcinoma who underwent contrast-enhanced breast MRI and the noncompressive breast MRE exams. CE-MRI shows that in the left breast, there is a heterogeneously enhancing mass in the right subareolar breast tissue corresponding to the biopsy-proven malignancy, with a size of 3.2 x 2.0 x 2.4 cm (Fig. 2(a), arrow). No abnormal indications were seen in the right breast. Breast MRE shows that the glandular tissue is heterogeneous in stiffness, and the carcinoma is much stiffer than the surrounding breast tissue (Fig. 2(b), arrow).

**Discussion:** All of the subjects who underwent the noncompressive breast MRE exam felt it was comfortable. Patient comfort in these exams was maintained, in part, by the design of the MRE driver, which does not compress the breast tissue. We also developed a custom pad, not specific for MRE, that replaces the original commercial pad used on top of the breast RF coil to support the patient. The small, noncompressive breast MRE technique may reduce any anxieties the patient may have for traditional breast MRE due to the lack of breast compression. In addition to maintaining patient comfort, this noncompressive driver design also can avoid the possible problem of breast tissue compression changing the observed tissue stiffness while also providing a possible "one size fits all" solution to fitting the MRE driver to patients with different breast sizes since this driver does not require any patient-specific adjustments. This driver design should be compatible with any existing RF coils that have a bridge to support the patient's sternum. The driver was able to deliver significant shear wave motion into both breasts in all subjects. The 3D GRE MRE acquisition successfully imaged the full volumetric breast wave field in all subjects and detected the invasive ductal carcinoma in the patient.

**Conclusion:** The noncompressive breast MRE technique is comfortable and compatible with a commercial breast RF coil. It has proven to be reproducible in a small cohort of healthy volunteers and identified an invasive ductal carcinoma as being significantly stiffer than normal adipose and glandular tissue. Future work will include recruiting a larger number of healthy and patient volunteers to assess the potential for this technique to characterize and differentiate suspicious breast lesions.

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**References:** 1. Warner, E., N Engl J Med, 2011. 365(11). 2. Breast Cancer Facts & Figures 2011-2012, American Cancer Society. 3. Hooley, R.J., Radiology, 2012. 4. Siegmund, K.C., Eur Radiol, 2010. 20(2). 5. McKnight, A.L., AJR Am J Roentgenol, 2002. 178(6). 6. Sadigh, G., Breast Cancer Res Treat, 2012. 134(3). 7. Barr, R.G., J Ultrasound Med, 2012. 31(6). 8. Chen, J., ISMRM 2987, 2012. 9. Glaser, K.J., ISMRM 4669, 2009. 10. Manduca, A., Med Image Anal, 2001. 5(4).

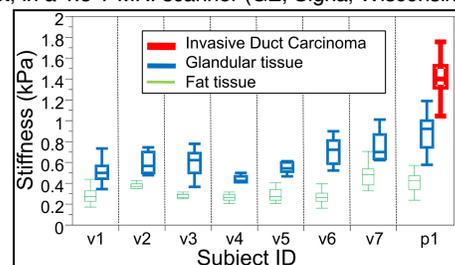


Fig. 1. Breast tissue stiffness in healthy and patient volunteers.

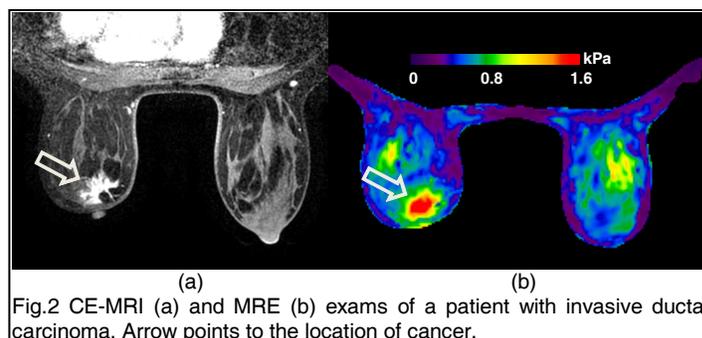


Fig. 2 CE-MRI (a) and MRE (b) exams of a patient with invasive ductal carcinoma. Arrow points to the location of cancer.