Non-Contact Driver System for MR Elastography of the Breast

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Introductions:

Breast cancer is one of the most commonly diagnosed life-threatening diseases in American women. It was estimated that in 2010 there will be 207,090 new breast cancer cases (28% of all new female cancer cases), and 39,840 deaths caused by breast cancer (15% of all female deaths due to cancer) [1]. Compared with x-ray mammography, contrast-enhanced MRI offers not only morphology information but also functional features such as tumor vascularization. CE-MRI has high sensitivity (89-100%), but a specificity as low as 30% [2]. A recent study showed that breast MR elastography (MRE), a technique for measuring the stiffness of breast tissue, can improve the specificity by 20% while maintaining the sensitivity near 100% when compared with CE-MRI alone [3]. As far as we know in the literature, previously reported breast drivers all have the same limitation that they must be in direct contact with the breast in order to transmit mechanical waves into the breast [3-7]. The disadvantages of direct-contact breast drivers are: (1) they add tension and change the shape of the breasts (factors whose effects on breast biomechanical properties are not yet fully understood); (2) the driver-breast mechanical coupling can be significantly affected by the size of the breasts; (3) The breast RF coils may require modification or customization to accommodate the driver, thereby limiting their use in clinical practice; and (4) driver presence could interfere with MRI-guided breast biopsy. To address these problems, we sought to develop a driver system suitable for bilateral breast MRE that does not directly contact the breasts and is compatible with existing RF coils. *Our hypothesis* was that this non-contact breast driver can generate suitable shear wave fields for MRE in both breasts. This abstract describes the driver design and the results of preliminary testing of this hypothesis.

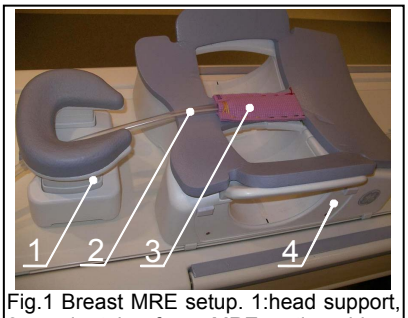

Fig.1 Breast MRE setup. 1:head support, 2:supply tube from MRE active driver, 3:breast driver, 4:RF coil.

Methods and Materials:

Volunteers: This study was approved by our Institutional Review Board (IRB). 4 healthy female volunteers were recruited after obtaining written informed consent (age range: 19-27 years, mean: 22.3). Driver design: The non-contact breast MRE driver (Fig. 1, #3) was fabricated as a small flexible strip (6.5 X 17 X 0.8 cm) constructed of an inelastic rubber sheet wrapped around a porous, springy foam filling material (as in [10]). This driver vibrated via 60-Hz harmonic, acoustic pressure variations transmitted from an active driver engine located outside the scan room. The pressure variations travelled through a 24-foot long, ¾-inch diameter PVC tube to a 1.8-foot long ½-inch diameter PVC tube coupled to the passive driver (Fig. 1, #2). The driver was positioned on the middle part, or bridge, of a standard breast RF coil (Liberty 9000 8-ch. breast coil, USA Instruments, Inc., Aurora, OH) (Fig. 1, #4). The volunteer was positioned normally - prone, feet first - on the coil with the driver in contact with the sternum. MRE sequence: A single-shot SE-EPI MRE sequence (Fig. 2) was used to collect volumetric bilateral breast MRE data on a 1.5 T scanner (GE, Wisconsin, USA). FOV = 27-44 cm; phase offsets = 3; 1 6.5-ms 3.2-G/cm motion-encoding gradient on each side of the refocusing pulse (motion sensitivity = 30 μm/π radians); imaging plane=axial; motion encoding in 3 orthogonal directions; matrix =72X72; NEX = 1; Bandwidth = ±250 kHz; TE/TR = 52.3/1333.8 msec; slice thickness = 5-10 mm; number of slices = 16-32; ASSET factor = 2; total scan time = 30-60 sec without breath-holding. Spatial saturation bands were positioned posterior to the breasts to suppress signal from the heart and lungs. Separate acquisitions were performed with the center frequency on the water and fat peaks. MRE inversions: The vector curl of the measured displacement data was calculated using 3x3x3 derivative kernels on the wrapped phase data [8]. A 3D local frequency estimation inversion was performed on the curl data with 3D directional filtering (cutoff frequency 0.1-80 wave/FOV) for calculating the MRE elastograms [9].

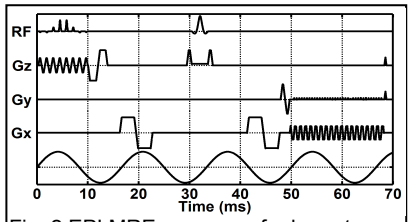

Fig. 2 EPI MRE sequence for breast imaging.

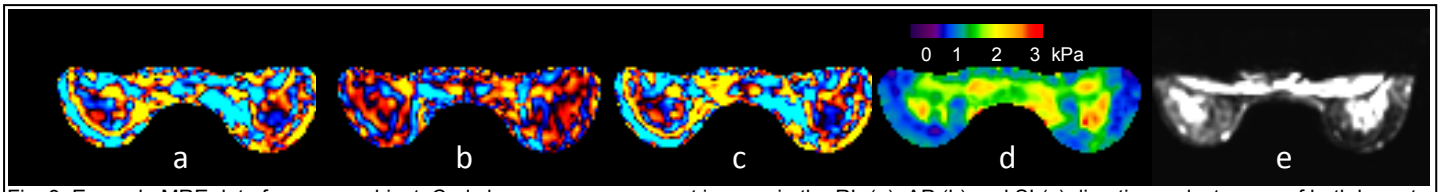

Fig. 3 Example MRE data from one subject. Curl shear wave component images in the RL (a), AP (b) and SI (c) directions; elastogram of both breasts (d) and magnitude image from the EPI MRE sequence (e).

Results:

The volunteer studies demonstrated shear wave illumination throughout both breasts, equivalent or better than obtained with previous direct contact driver systems. Fig. 3 shows MRE results from one volunteer with data collected at the water center frequency only. Fig. 3(a, b, c) are the components of the vector curl shear wave images at the center of the breasts (RL, AP, SI directions, respectively). Fig. 3(d) is the elastogram and Fig. 3(e) is the magnitude image from the EPI MRE sequence.

Discussion:

Although the driver is mainly coupled to the sternum, testing showed that the device successfully generates extensive shear wave motion in both breasts at 60 Hz. Since the width of the current driver is 6.5 cm, it could potentially contact and add some pressure to the medial edge of the breast in some women. A narrower driver may reduce these effects. The results indicate that the non-contact breast MRE driver design is promising. The combination of an effective driver system that is compatible with existing RF coils and an EPI MRE sequence that provides 3D wave imaging in acquisition times of 30-60 seconds has provided the key prerequisites for further clinical studies of the potential value MRE for assessment of breast cancer.

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References:

[1].Jemal, A., et al., 2010. CA Cancer J Clin. 60(5): p. 277-300. **[2]**.Kuhl, C., Radiology, 2007. 244(2): p. 356-378. **[3]**. Sinkus, R., et al., Magn Reson Med, 2007. 58(6): p. 1135-44. **[4]**. Siegmann, K.C., et al., Eur Radiol. 20(2): p. 318-25. **[5]**.McKnight, A.L., et al., AJR Am J Roentgenol, 2002. 178(6): p. 1411-7. **[6]**. Van Houten, E.E., et al., JMRI 2003. 17(1): p. 72-85. **[7]**. Plewes, D.B., et al., Phys Med Biol, 2000. 45(6): p. 1591-610. **[8]**. Glaser, K.J., ISMRM 4669., 2009. **[9]**. Manduca, A., et al., Med Image Anal, 2001. 5(4): p. 237-54. **[10]**. Chen, J., et al., ISMRM 2010, 1052.