Progress in Phased-Array Mechanical Drivers for Magnetic Resonance Elastography

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Introduction:

Magnetic Resonance Elastography (MRE) uses a phase-contrast MR imaging technique to visualize propagating shear waves in order to measure the stiffness of tissue (1). Typically, a single mechanical driver is used to produce these waves, which in some cases have certain limitations that include attenuation and shadowing artifacts. It had been shown previously that these limitations could be addressed by using multiple drivers with an 8-driver phased array acoustic driver setup (2). It was also shown that by adjusting the phases of these drivers, any arbitrary region of interest can be optimally illuminated (2). The purpose of this work was to investigate the opportunities offered by driver arrays with an even larger number of independent elements and the potential to improve stiffness estimation in MRE.

Materials and Methods:

A 1.5-T whole body scanner(GE Signa, Milwaukee, WI) and Helmholtz surface coil were used for the experiments. A cylindrical gel phantom of 20-cm diameter and 7-cm height was made with 2% agar. In some experiments, a 4% agar gel of dimensions 2.5 cm × 2.5 cm × 7 cm was also included in the phantom. A setup of eight electromechanical drivers, with 2 Ω resistance in each coil, was placed in the phantom. All the eight drivers were driven simultaneously, by using a commercially available 8-channel 16-bit analog output board (PD2-AO-8/16). Previously, individual driver data were also obtained for all the eight drivers. These individual data were added together and then compared with the simultaneously driven 8-driver data. The 8-driver setup was rotated by 11.25 degrees three times and then these four sets of 8-driver data were added to create 32-driver data. 64-driver data was similarly created. Also, “Comsol Multiphysics,” a finite element modeling software, was used to simulate individual and multiple driver datasets.

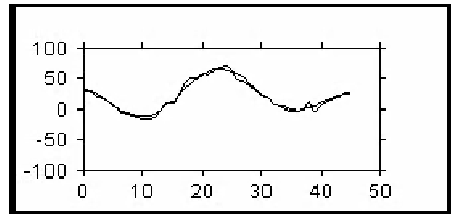

Fig 1.Line profile comparisons of the simultaneously driven wave data and the offline reconstructed 8-driver data.

Results and Discussion:

Fig. 1 shows a comparison of the line profiles from the simultaneously driven 8-driver dataset and the offline reconstructed 8-driver dataset. Both the profiles were almost identical indicating that the performance of the larger multiple driver datasets could be predicted by adding individual driver datasets. Fig 2 shows the wave images of the predicted data sets showing 4, 8, 16, 32 and 64 drivers. A comparison of the line profiles shown by the white lines in Fig 2a are shown in Fig 2b and Fig 2c. From these two comparisons, it is clear that as the number of drivers increase, the wave amplitude increases. This will result in an increase in the signal-to-noise ratio and the phase-to-noise ratio and thus will yield a better estimate of the stiffness of the tissue. Fig 3 shows a result of finite element simulated phase optimization for the 32 drivers case. Fig 3a shows the set up with the soft background and a square stiff inclusion. Figs 3b and 3c show one wave image with the driver phases adjusted to give maximum displacement at the square inclusion with eight and thirty two drivers. The region of optimization is shown by the red square. Figs 3d and 3e show the stiffness estimates obtained from the wave data shown in figs 3b and 3c. The stiffness estimate obtained from the 32-drivers case is more uniform in the background and the edges of the inclusion are better identified.

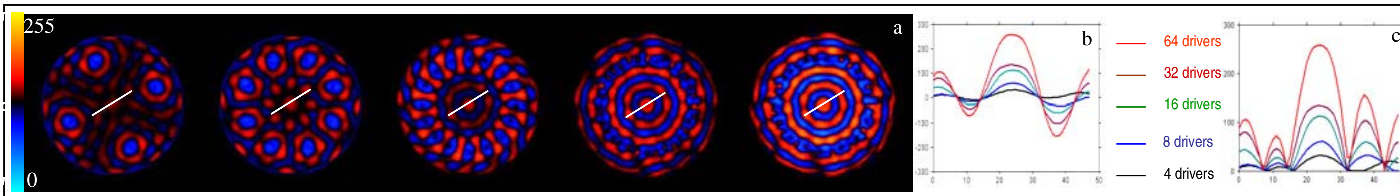

Fig 2 (2a.) A wave image of an inclusionless phantom with 4, 8, 16, 32 and 64 drivers are shown. The white lines show the line profiles. (2b) A line profile comparison for the five data sets. The legends of these lines are also shown. (2c) The magnitude comparison of these five line profiles are shown.

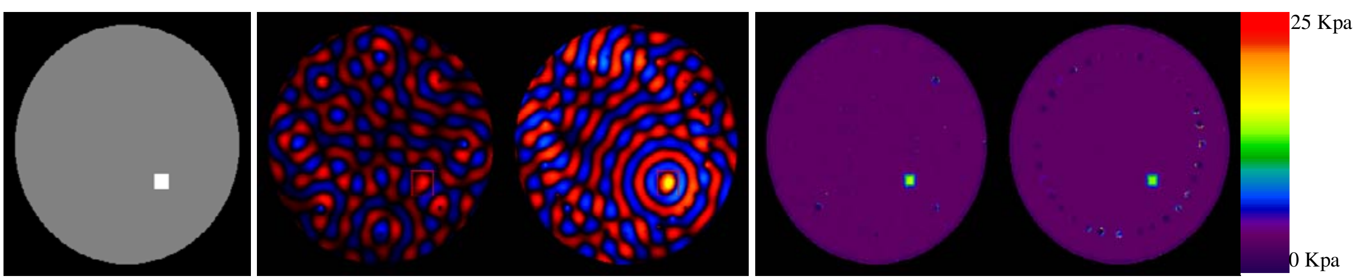

Fig 3. (3a) Setup of the phantom with softer background and stiffer inclusion. (3b) Wave image of the phantom with phases of the 8 drivers adjusted to give higher displacement in the inclusion. (3c) Wave image of the phantom with phases of the 32 drivers adjusted to give higher displacement in the inclusion. (3d) Stiffness estimate of the phantom for the8drivers phase optimization (3e) Stiffness estimate of the phantom for the 32 drivers phase optimization

Conclusion:

The results indicate that the displacement at a region of interest can be increased both by increasing the number of drivers and adjusting the phases of these drivers optimally. There is evidence that development of driver arrays with 16-32 elements may provide practical advantages over 8 driver arrays. The use of multiple drivers in elastography could be advantageous in applications such as breast MRE where the organ is easily accessible for the placement of multiple drivers and where the attenuation artifacts are more pronounced.

Reference:

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