Investigation of patient positioning and MRE driver placement on Cardiac MR Elastography

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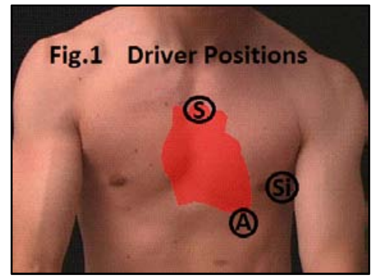
Target audience: Cardiac radiologists**,** physicians, scientists, and engineers interested in cardiac magnetic resonance elastography (MRE) applications.

Purpose: Normal cardiac function is dependent on the mechanical properties of the myocardium [1]. As a result, being able to measure the stiffness of myocardial tissue *in vivo*, could have significant diagnostic and prognostic value. MR elastography (MRE) is a phase-contrast technique capable of making non-invasive stiffness measurement *in vivo* [2]. A typical MRE exam is composed of 3-steps, i) actuation, ii) acquisition, and iii) inversion. Step one involves the generation of shear waves inside the tissue of interest, usually with what is referred to as an active driver. In the second step, the measurement of the displacement field created by the propagating shear waves is measured using MR phase contrast imaging. Lastly, the shear wave displacement field is used to calculate a stiffness map (elastogram), commonly referred to as inversion. Kolipaka et al. [3], recently demonstrated the feasibility of cardiac MRE in a pig model. The authors showed that MRE was able to successfully assess regional differences in stiffness between infarcted and remote non-infarcted tissue regions. One of the key challenges in translating this technology into a clinical setting, however, is getting adequate frequency and amplitude shear waves into the heart. This is primarily due to the high attenuation of shear waves in intermediate tissue between the driver and heart. Due to this challenge, Kolipaka et al. were required to perform open heart surgery, in order to generate vibrations directly on the surface of the porcine heart. Hence, there is a need to investigate new approaches to non-invasively generate shear waves inside the heart. Before designing a driver for the purposes of MRE it is important to understand the optimal position to place a driver in order to perform cardiac MRE. While conventional cardiac MRI scans are performed in the supine position this may not be the optimal patient positioning for this application. In the prone position, the heart may compress the tissue between the sternum and the heart wall, potentially reducing the distance shear waves need to travel before reaching the heart surface. Additionally, due to the unique anatomical location of the heart within the chest cavity, it is currently unclear what the optimal position is for generating waves. The purpose of this study is to evaluate and compare wave amplitudes at different patient and driver positions.



Methods: A healthy 30 year old female volunteer was scanned using an ECG gated 2D FGRE MRE sequence with 22 s breath holds, in both supine and prone positions. Vibration frequency of 100 Hz was used for MRE imaging, with the driver placed in three different positions (Figure 1); on the sternum **(S)**, near the apex of the heart **(A)**; and at the side of the body (**Si**). For comparison, at each driver placement location, no motion scans were performed. A single channel surface coil was used for imaging, and a respiratory belt was used to monitor breath holds. All MRE experiments were performed with a 1.5-T whole-body scanner (Signa EXCITE, GE Healthcare, Milwaukee, WI). The scan parameters were FOV = 20 cm; slice thickness = 10 mm; TR = 22.5; TE =14.6; flip angle = 30, and a scan matrix of 128x96. The wave images were analyzed using MRE lab software. The magnitude of the first harmonic with respect to time was calculated for each set of wave images. Amplitude maps were obtained from the displacement images in the superior-inferior, right-left, and anterior-posterior directions for both the no motion and motion cases. The amount of displacement generated in the heart was evaluated by subtracting the no-motion displacement amplitudes from the motion displacement amplitudes. A small circular region of interest was chosen at the center of the ventricular septum wall for comparison across different driver locations and patient positions.

Results: Magnitude images displaying the heart locations in supine and prone positions are shown in Figure 1A and B, respectively. The corresponding displacement difference images obtained while the driver was located on the sternum, and the volunteer was in the supine and prone positions has been shown in Figure 1B and D, respectively. The calculated displacements in the ventricular septum are shown in Table 1 for all driver placements and volunteer positions.

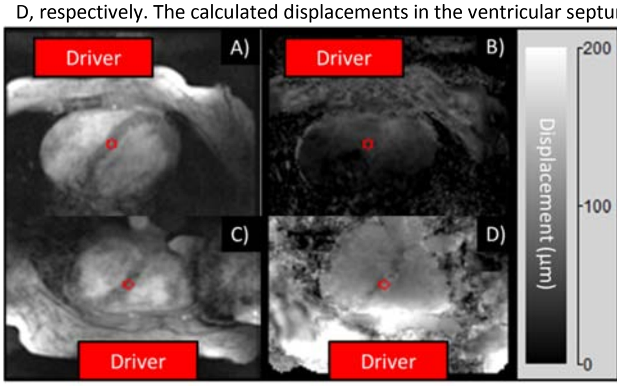


Figure 1: Magnitude images of the heart while the driver is positioned on the sternum and the patient is in the A) supine and C) prone position. The corresponding amplitude difference images for the B) supine and D) probe positions. The red circle shows the size and location of a typical region of interest used to measure displacement amplitudes.

Table 1: Measured displacement values in the ventricular septum.

	Supine	Prone
Apex	20±8 µm	27±4 µm
Sternum	31±4 µm	84±6 µm
Side	-4±6 µm	5±2 µm

Discussion: The objective of this study was to determine the optimal driver and patient positioning for cardiac MRE. From Figure 1A and C it appears that the heart moves closer to the chest wall in the prone position as compared to the supine position. The intermediate tissue also seems to be more compressing in the prone position. The maximum displacement amplitude in the ventricular septum was measured while the volunteer was in the prone position and the driver was on the sternum. An almost 3 fold increase was observed in the prone position than in the supine position, which is clearly demonstrated in Figure 1B and D. In other driver location (apex, side), however, significant changes in displacement amplitudes between the two positions was not observed. One explanation for this is the fact that the volunteer was lying directly on the driver when the driver was placed on the sternum, potentially improving coupling. Another potential explanation is that the heart is better coupled with the sternum, while it rests on the intermediate tissues. This implies that higher amplitude waves can be transmitted into the myocardium resulting in higher signal to noise in the MRE wave images that can potentially yield more robust and accurate stiffness measurements of the myocardium. One of the limitations with using this technique however, is the volunteer reported discomfort while lying in the prone position. Another limitation with this study is that it has been tested in only a single volunteer. Future studies investing this approach will help in verifying this finding.

Conclusions: It is found that SNR can be improved at 100 Hz within the myocardium when a volunteer is placed in the prone position with the driver placed on the sternum. This outcome has now opened new avenues of research in this direction towards the technical development of cardiac MR Elastography which has the potential to be used to measure myocardial stiffness *in vivo*.

References: [1] Holmes JW, Ann Rev Biomed Engg 2005;7:223-253. [2] Muthupillai R, et al, Science 1995;269:1854-1857. [3] Kolipaka A, et al, Proc. Intl. Soc. Mag. Reson. Med. 2011;19,15.