MR Elastography of the *In Vivo* Abdominal Aorta: Feasibility Study

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Background: Hypertension affects over 140 million people in North America, many of which do not know they have it. This condition is one of the most important risk factors in the development of cardiovascular diseases leading to premature death. Hypertension and subsequent arterial stiffness are determined by vascular smooth muscle tone and by the elastin/collagen content of the vessel wall [1]. To date there is no noninvasive method to determine the stiffness of abdominal aorta. Magnetic resonance elastography (MRE) is a novel imaging technique that can image the response of the tissue to externally-generated acoustic waves to obtain the intrinsic mechanical properties of the tissue [2-4]. Our hypothesis is that MRE can be used to image early hypertensive changes from stiffness measurements enabling targeted therapy and prevention of secondary cardiovascular disease. The purpose of this study is to demonstrate feasibility of using MRE to identify hypertensive changes in the abdominal aorta when compared to normals based on the stiffness measurements.

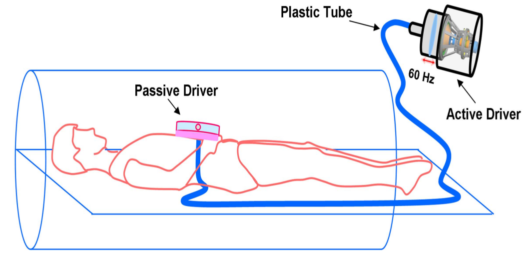

Figure 1. A pneumatic drum driver is placed on the chest wall. Sound waves are transmitted through a hollow plastic tube to the passive driver and into the volunteer's abdominal aorta.

Methods: *In vivo* aortic MRE was performed on 3 normals (25-45 years old Male) and one hypertensive (66 years old Female) volunteer with a long history of hypertension currently controlled on antihypertensive medications. All imaging was performed in a 1.5-Tesla MRI scanner (Signa Excite, GE Health Care, Milwaukee, WI). The volunteers were positioned in the supine position and placed feet first into the scanner as shown in figure 1. A gradient echo MRE sequence [5] was used to acquire a sagittal slice. Mechanical waves were introduced into the abdominal aorta by a pneumatic driver system as shown in figure 1. The passive driver was placed just inferior to the xiphisternum. Imaging parameters included TE/TR= 50,66/25,24 ms; FOV= 24,32,40 cm; α= 30°; slice thickness= 5,8 mm; acquisition matrix= 256x96; excitation frequency= 60 Hz; 4 MRE time offsets; and 16.67-ms duration (60 Hz) motion encoding gradients were applied separately in the x, y, and z directions to measure the in-plane and through plane motion. These images were acquired in a free breathing mode. The sagittal images in all the volunteers were masked to obtain abdominal aorta for processing as shown in figure 2 indicated by red line. The x, y and z components of motion were analyzed to obtain effective stiffness maps using direct inversion algorithm.

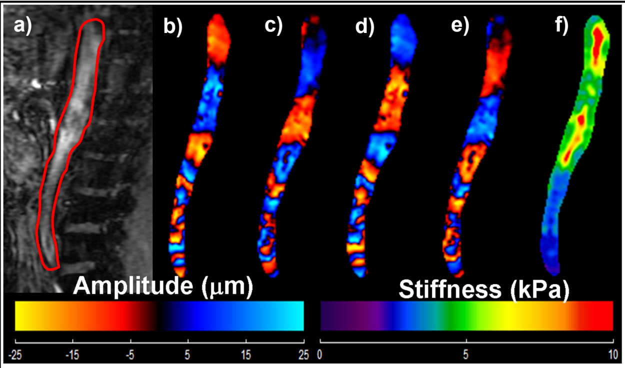

Figure 2. Normal Volunteer a) Sagittal magnitude image of the abdominal aorta indicated with red contour. **b-e)** The four phases of the in-plane component of the propagating waves and **f)** Weighted stiffness map from 3 encoding directions with a mean stiffness of 5.2±2.7 kPa.

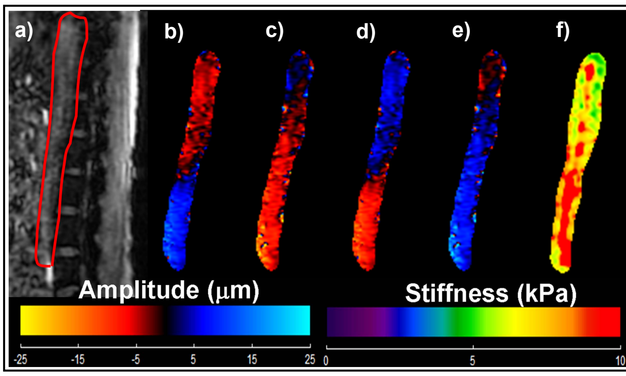

Figure 3. Controlled Hypertensive Volunteer a) Sagittal magnitude image of the abdominal aorta indicated with red contour. **b-e)** The four phases of the in-plane component of the propagating waves and **f)** Weighted stiffness map from 3 encoding directions with a mean stiffness of 8.9±4.4 kPa.

Results: The experimental results demonstrated that propagating mechanical waves could be visualized in the abdominal aorta in all 4 of the volunteers examined as shown in figures 2 and 3. When no external motion is applied no discernible waves were imaged indicating MRE is insensitive to the physiological motion of the aorta. Figure 2 (a-e) shows an example of magnitude image of abdominal aorta with a red contour delineating aorta and the corresponding phase images of the in-plane component (i.e. x) of propagating waves in one of the normotensive (i.e. normal) volunteer. Figure 2(f) shows the weighted stiffness map from 3 encoding directions using direct inversion algorithm with a mean stiffness of 5.2±2.7 kPa. Figure 3 (a-f) shows the magnitude image and phase images of propagating waves in the controlled-hypertensive volunteer and the corresponding weighted stiffness map from 3 encoding directions using direct inversion algorithm with a mean stiffness of 8.9±4.4 kPa. The normotensive group demonstrated an average abdominal aortic stiffness of 4.6 ± 1.7 kPa, while the controlled-hypertensive demonstrated an average abdominal aortic stiffness of 8.9 ± 4.4 kPa.

Discussion:
The results indicate that this MRE technique is feasible and can be used to examine the stiffness of the abdominal aorta. Furthermore, the early data suggest that there may be discernible differences in effective stiffness measurements between normotensive and hypertensive individuals and that these differences persist even after control with medication. In this work, the reported stiffness measurements are not absolute but relative since the inversion algorithm does not take into account true 3D wave propagation as well as geometry of the object. Future work will concentrate on incorporating these factors into account.

References:
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