

magnetic resonance elastography of the human abdominal aorta: a preliminary study

Lei Xu^{1,2}, Jun Chen¹, Kevin J Glaser¹, Meng Yin¹, Phillip J Rossman¹, and Richard L Ehman¹

¹Radiology Department, Mayo Clinic, Rochester, MN, United States, ²Radiology Department, Beijing Anzhen Hospital, Capital Medical University, Beijing, Beijing, China, People's Republic of

Introduction: In recent years, great emphasis has been placed on the role of arterial stiffness in the development of cardiovascular diseases. The aorta is a major vessel of interest when determining regional arterial stiffness for the reason that the thoracic and abdominal aorta makes the largest contribution to arterial buffering [1]. Studies also suggest that increased arterial stiffness is related to the formation and rupture risk of aneurysms of the abdominal aorta [2]. There is a need for a reliable, noninvasive method of detecting early disturbances in arterial stiffness at a time when therapeutic intervention can be most beneficial. Prior studies have shown that MRE has the potential to evaluate the elastic properties of vessel walls by imaging propagating mechanical waves within fluid-filled vessels [3,4]. In this work, phantom and in vivo studies were conducted to determine whether MRE can reliably image externally applied mechanical waves within the aorta. The hypothesis of this study is that MRE can assess the mechanical properties of the aortic wall in vivo by imaging these waves using a pulse-gated MRE acquisition.

Methods: To validate the experimental approach proposed for imaging the aorta in vivo, a gel phantom with an embedded porcine aorta was used to demonstrate that externally produced motion could be transmitted into the aorta and imaged even in the presence of fluid flow within the aorta. To investigate the potential changes in the elasticity of the vessel wall with changes in pressure, different static pressures from 20 to 120 mmHg were applied. MRE data were acquired with a gradient-echo MRE sequence and the stiffness of the aortic wall under the different pressures was calculated. Shear wave visualization in the aorta during dynamic pulsatile flow was performed using a gated cine gradient-echo MRE pulse sequence. The feasibility of performing MRE of the abdominal aorta was assessed in five healthy male volunteers (32 ± 7.4 years). A passive driver produced vibrations on the abdominal wall that were transmitted through the abdomen and to the abdominal aorta. The pulse-gated cine MRE technique was used to study the wave propagation along the aorta throughout the cardiac cycle and provide estimates of aortic stiffness in diastole.

Results: In the phantom study, the wave propagation was well visualized within the porcine aorta embedded in the gel phantom. An increase of the Young's modulus-wall thickness ($E \cdot t$) product with the increase in static pressure was observed. Wave propagation along the vessel lumen was well demonstrated in the presence of pulsatile flow during diastole, but was not well visualized during systole due to significant fluid flow. In the in vivo study, the waves were well visualized within the lumen of the abdominal aorta in all of the five healthy volunteers in the diastolic phase, but they were not well visualized during systole. (Fig. 1) A significant correlation between $E \cdot t$ product of aortic wall in the five volunteers and their age was revealed ($r^2=0.81$, $p<0.05$). (Fig. 2)

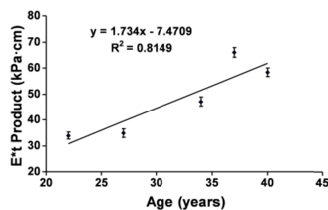
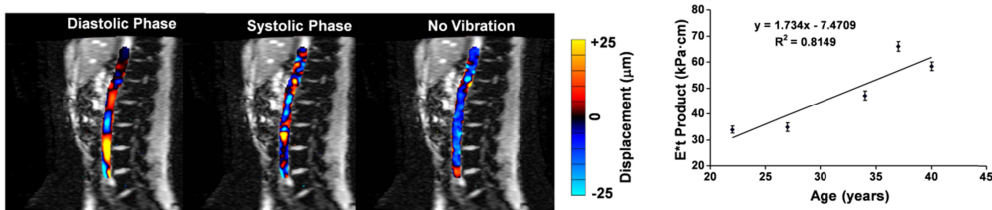


Fig.2 Relationship between the estimated stiffness of the aortic wall and the age of volunteers. A significant correlation was observed ($p < 0.05$).

Fig.1 Wave images masked and overlaid on the magnitude images obtained with the pulse-gated cine MRE sequence in the abdominal aorta. Wave images are shown at diastolic and systolic phase. Wave data with no external vibration during diastole shows no waves are present.

Discussion and Conclusion: In this study, we investigated the feasibility of using MRE to assess the mechanical properties of the aortic wall in vivo by imaging the propagation of externally produced mechanical waves within the abdominal aorta. We believe this work provides preliminary evidence that the mechanical properties of the in vivo aorta can be measured with MRE. This methodology potentially offers a new noninvasive method for the evaluation of arterial wall mechanical properties.

References: [1] Laurent S, et al. *Eur Heart J*. **2006**;27:2588-605. [2] Dijk JM, et al. *Stroke*. **2004**;35:1642-6. [3] Woodrum DA, et al. *Magn Reson Med*. **2006**;56:593-600. [4] Woodrum DA, et al. *J Magn Reson Imaging*. **2009**;29:583-7.