Quantification of Aortic Stiffness Using MR Elastography and its Comparison to Pulse Wave Velocity: Early Validation

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Target Audience: Biomedical researchers, cardiovascular and radiology physicians, technologists etc.

Introduction: Arterial (aortic) stiffness is a well-recognized pathophysiological change that plays a significant role in the determination of risk factors for various cardiovascular diseases including hypertension, atherosclerosis and coronary artery disease [1]. While many factors contribute to the stiffening of arteries, increasing age of the individual is one of the most important causes [1]. Presence of other conditions such as hypertension (common in older people), may contribute or even accelerate the process, independently or in conjunction with aging. Early detection of arterial stiffness could significantly impact the management and patient outcomes. Currently, many techniques, both non-invasive and invasive, are in clinical use for the assessment of arterial stiffness. Measurement of pulse wave velocity (PWV) is the gold standard among non-invasive modalities. It is actively being utilized in both clinical and research areas for many years to determine the stiffness of aorta, for example, in hypertensive patients. Recently, a novel non-invasive MRI based technique known as magnetic resonance elastography (MRE) was developed to determine the stiffness of the aorta [2]. The aim of the study is to compare the MRI based PWV measurements in the aorta against MRE based stiffness measurements in normal volunteers with increase in age.

Methods: In-vivo aortic MRE and MRI was performed on 14 healthy volunteers; 8 from ages: 18-35 years and 6 from ages 50-65 years. All imaging was performed using a 3T-MRI Scanner (Tim-Trio, Siemens Healthcare, Germany). The volunteers were positioned in the supine position and placed head first in the scanner. 60Hz mechanical waves were introduced in to the aorta using a pneumatic diver [2]. A gradient echo-MRE and phase contrast (PC)–MRI sequences were performed to obtain wave and velocity data on a sagittal slice of the aorta. The imaging parameters for MRE included: TE/TR=21.3/25ms, matrix =128x64, FOV=40cm, α =16˚ and a motion encoding gradient of 60Hz was applied separately in the x, y, and z direction to encode motion. The imaging parameters for the PC-MRI included: TE/TR=2.1/9.15ms, venc=150,175cm/s; matrix=192x144, FOV=30x40cm^2, α =15˚, # of cardiac phases=128. The sagittal images were masked to obtain the major portion of the aorta for both MRE and PC-MRI data analysis. Then, MRE wave images were analyzed using MRE-Lab (Mayo Clinic Rochester, MN) to obtain the stiffness of the aorta [3]. PC-MRI phase images were analyzed using in house custom built software in Matlab (Mathworks, Natic, MA) to obtain the PWV measurements [4].

Results: Figure 1 a-e shows the sagittal magnitude image with the contours used for segmenting the abdominal aorta and corresponding snap shots of wave propagation in one of the volunteers. Figure 1f shows the weighted stiffness map from 3 encoding directions with a mean stiffness value of 4.3±0.8kPa. In figure 2a white line represents the region along the aorta where the foot of the pulse wave was tracked and plotted using distance Vs. time to obtain the PWV in the same volunteer (figure 2b). Figure 3a shows the plot of MRE derived stiffness as a function of age demonstrating linear increase in stiffness with an R^2 value of 0.65. Similarly, figure 3b shows the plot of PWV as a function of age with linear correlation of R^2=0.7.

Discussion: We have observed that MRE derived stiffness and PWV measurements increased linearly with increase in age. Furthermore, this study demonstrated the feasibility of comparing MRE derived stiffness estimates and PWV measurements in the same imaging plane of the aorta. However, PWV only provides global measure of stiffness, whereas MRE provides spatial stiffness maps of the aorta. More studies are warranted to establish the correlation between MRE-derived stiffness and PWV.

References: ***1.*** *Agabiti-Rosei et al. Vasc Health Risk Manag. 2009;5: 353–60.* ***2.*** *Kolipaka A et al. JMRI 2012; 35(3):582-86.* ***3.*** *Manduca A et al. Med Image Anal. 2001 Dec;5(4):237-54.* ***4.*** *Giri S et al.* Computers in Cardiology 2007;34:661–664.

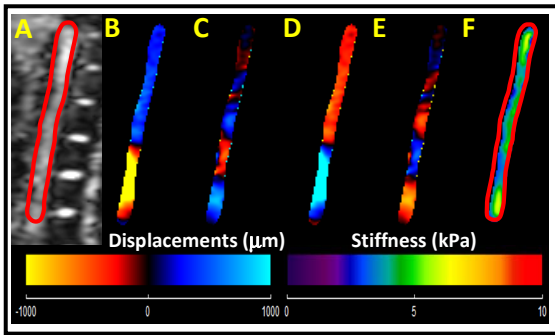

Figure 1. **A:** Magnitude image with red line segmenting abdominal aorta. **B–E:** Snap shot of four phases of propagating waves. **F:** The weighted stiffness map from x, y, and z encoding directions with a mean stiffness of 4.3kPa.

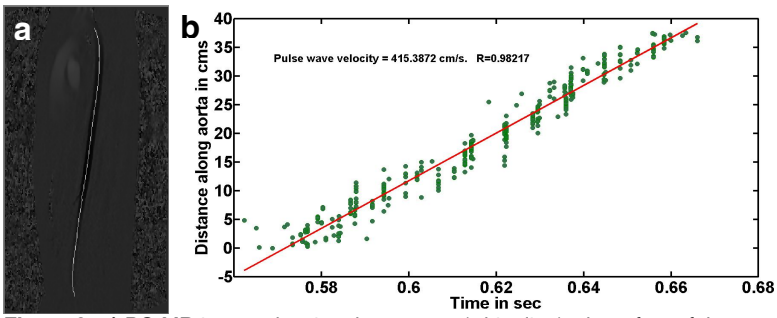

Figure 2: a) PC-MR image showing the contour (white line) where foot of the pulse wave is tracked along the aorta. **b)** Plot of distance along the aorta (where foot of pulse wave is tracked) as a function of time. The slope from the plot provides PWV of 4.15m/s.

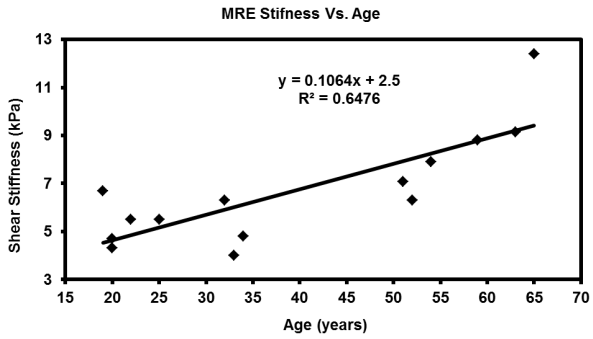

Figure 3a: MRE aortic stiffness as a function of age

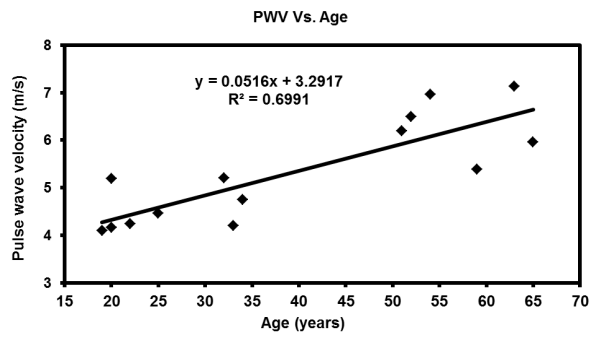

Figure 3b: Pulse wave velocity as a function of age