MRI estimate of central and peripheral pulse-wave velocity via velocity-encoded projections

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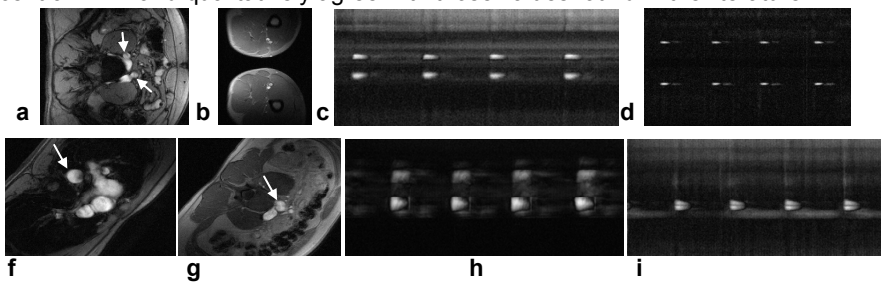
Introduction Stiffening of the aorta results in increased pulse wave velocity (PWV), the propagation velocity of the blood motion. Aortic stiffness has been shown to correlate with aging [1], but is also indicative of atherosclerotic alterations and as a measure of cardiovascular risk [2]. Quantification of peripheral PWV (e.g. iliac, femoral and popliteal arteries) has received much less attention but a few studies indicate peripheral PWV may be preferable as a marker for vascular disease. Unlike aortic PWV, peripheral PWV does not increase with age [3], it may be more specific to the presence of early systemic atherosclerosis. The descending portion of the aorta is typically imaged in an oblique sagittal or coronal plane [4] but this approach is not suited for visualizing the peripheral arteries due to increased tortuosity and reduced vessel diameter. Here, we introduce a non-triggered projection-based method for quantifying PWV of the descending aorta and the segment extending from the abdominal aorta to both femoral arteries to complement aortic PWV [5]. Preliminary results are consistent with values found in literature.

Methods In order to quantify PWV along two distal arterial sites we acquire velocity-encoded projections at both locations after exciting them essentially simultaneously with two successive RF pulses of different frequencies. Temporal resolution of 12 ms (TR=6 ms) was achieved by sampling only the *center k-space line* $k_y = 0$ repeatedly with two-step velocity-encoding to map the complex difference (CD) signal intensity during the cardiac cycle. CD between velocity-encoded projections retains only signal from the moving spins and represents average signal across the lumen in the projection direction (perpendicular to the readout direction). At the onset of systole (flow velocity << v_{max}), thus CD intensity is proportional to velocity. For example, $\sin\phi$ and ϕ will differ by less than 5% even at $v=0.5v_{max}$ with VENC~$1.33v_{max}$. Thus, absolute quantification of velocity is not necessary since the propagation time of the pressure wave is estimated near the "foot" of the wave ($v<0.5v_{max}$) where |CD| is proportional to velocity. The major benefits of |CD| over velocity mapping are insensitivity to patient motion and much simpler post-processing. For details of the "foot-to-foot" approach to estimate propagation time from time-resolved |CD| curves, see [5]**.** A velocity-encoded GRE pulse sequence was used (FOV=356 mm, voxel size 1.32 x10 mm^2, TE/TR=4.0/6.0 ms, bandwidth=893 Hz/pixel, flip angle=20^o, VENC ranging from 150 to 250 cm/s, and slice separation distance of 240 to 400 mm). All studies were performed at 3T system (Siemens Tim Trio) using two body matrix coils placed on the chest and abdomen or abdomen and upper thigh area.

Results **Figs 1a, b** show axial images of iliac (white arrows) and femoral arteries acquired simultaneously with dual RF excitation. **Figs 1c, d** are the corresponding time-resolved projection |CD| images of iliac and femoral arteries. **Fig 1e** is a sample |CD| intensity curve computed from the projection images in **Figs 1c,d**. Similarly, **Figs 1 f, g** show axial images below the pulmonary artery and of the abdominal aorta proximal to the aorto-iliac bifurcation. **Figs 1h, i** are the corresponding |CD| images. **Table 1** lists the average PWV and standard deviations over 8-10 heart-beats for three healthy male subjects. As expected, peripheral PWV values are larger than the central PWV and qualitatively agree with those values found in the literature.



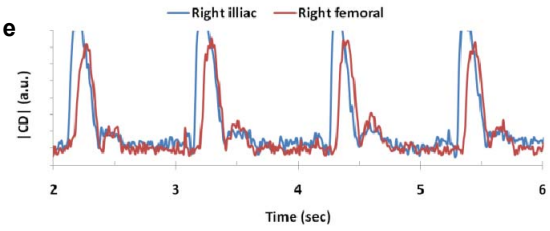


Figure 1 Determination of PWV from distal descending to abdominal aorta and from iliac to femoral arteries. Axial view of **a**) iliac (white arrows) and **b**) femoral arteries; c d) Four systolic peaks of projection |CD| signal intensity of iliac (**c)** and femoral arteries (**d**). **e**) Profiles of |CD| signal demonstrating the lag in the velocity wave between iliac and femoral arteries**. f, g**) Axial views of proximal descending (**f**) and abdominal aorta (**g**) (arrows) with corresponding |CD| images (**h, i**).

Table 1 PWV of central and peripheral arteries

Age	Aortic arch (m/s)	Thoracic/abdom. aorta (m/s)	Iliac/fem a. (m/s)
33	5.6± 0.2	6.6± 0.9	7.4± 1.2
38	5.9± 0.4	5.0± 0.5	8.9± 0.8
38	5.9± 0.3	3.8± 0.1	7.2± 0.4

Conclusions and Future Prospects We demonstrated the feasibility of PWV quantification in central and peripheral arteries with a projection-based non-gated method achieving 12 ms temporal resolution. PWV of central and peripheral artery can be used to assess the *gradient* of central-to-peripheral arterial stiffness and may provide useful clinical information. A reduced PWV gradient (i.e. vascular impedance matching between central and peripheral arteries) will increase transmission of potentially damaging pressure waves to the peripheral microcirculation, which can lead to what has been termed 'microvascular disorder [3].'

References:[1] Laurent et al, Eur Heart J 2006; [2] Blacher et al, Hypertension 1999; [3] Mitchell et al, Hypertension 2004; [4] Rogers et al, JACC 2001; [5] Langham et al, MRM 2010 (in press).

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