2D versus 3D aortic distance measurements for MRI-based pulse wave velocity analysis

Arna van Engelen, Miguel Vieira, Tarique Hussain, Jordi Alastruey

Division of Imaging Sciences & Biomedical Engineering, King's College London, London, United Kingdom

Introduction

- Measuring aortic stiffness by **pulse wave velocity** (PWV) is of great interest for the assessment of vascular disease.
- To determine PWV using **MRI** you usually need:
  - **Flow curves** from 2D phase-contrast (PC) images at two or more locations
  - The **distance** between those locations
- To measure distance, a sagittal 2D cine of the aorta or a 2D projection/ reformatting is often used. However, these images do not capture the **full 3D aortic geometry**.
- Additionally, the ascending aorta shows **considerable movement** throughout the cardiac cycle, increasing measurement inaccuracies.

Therefore our **Goal** was to:

Investigate differences in distance measurements from a 2D plane at end-diastole, end-systole and 3D MRI (end-systole), and the effect on computed PWV values

Method

- **Twelve individuals** (age 73±3, all female) were included.
- Acquired MRI images:
  - Cross-sectional **2D PC-MRI** of the ascending (ASC), descending (DESC) and diaphragmatic (DIAPH) aorta (1x1mm, thickness 8mm)
  - sagittal **2D cine** of the aorta (figure 1A)
  - cross-sectional **3D black-blood** (BB) images (figure 1B) of the aorta
- Manual distances measurements:
  - from the 2D cine at both ED and ES (using Osirix)
  - from the 3D-BB images (at ES) using three orthogonal views to identify the centre of the vessel (Figure 1B) (Mevislab). 3D measurements were averaged over three repetitions and used as ground truth measurements.
- Flow curves (Figure 2) were obtained using the extended MR Workspace (R2.6.3.1, Philips Healthcare).
- Transit times for PWV computations were determined using the foot-to-foot method [1].
- Statistical comparison was performed by Friedman testing.

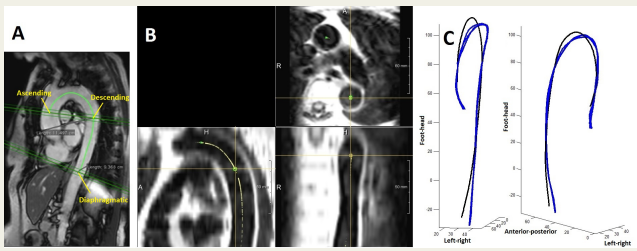

Figure 1: Distance measurements in 2D and 3D
A. Manual annotation in 2D with projection of the image slices for flow acquisition
B. Manual annotation in 3D
C. 3D display for comparison on 2D (black) and 3D (blue) curves

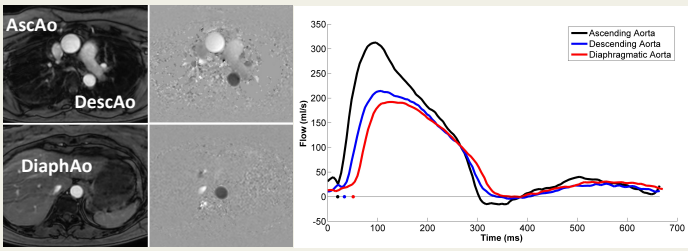

Figure 2: Phase-contrast MRI and corresponding flow curves for the ascending, descending, and diaphragmatic aorta for one subject. The determined foot of each flow curve is projected onto the horizontal axis

Results

- Results for distance measurements and PWV computation are shown in the table below.
- All individual distance measurements are also shown in Figure 3.
- For the aortic arch (ascending-descending aorta) the differences **between 2D-ED and 3D-ES measurements** were statistically significant ($p<0.05$).
- The **absolute differences** between 3D and 2D-ED for the ascending-descending aorta were:
  - Distance: 0.6±0.5 cm, range 0-1.7 cm
  - PWV: 0.5±0.5m/s, range 0.0-1.5 m/s
- The **relative difference** for both distance and PWV was 5.5±3.9%. (range 0.3 – 12.7%)

	Distance (cm)			PWV (m/s)		
	2D-ED	2D-ES	3D-ES	2D-ED	2D-ES	3D-ES
ASC-DESC	12.1±1.4	11.9±1.3	11.7±1.6	10.5±4.6	10.5±4.7	10.2±4.4
DESC-DIAPH	10.9±1.5	10.9±1.5	10.8±1.5	11.9±7.7	11.9±7.6	11.7±7.6
Total	23.0±1.9	22.8±2.0	22.5±2.3	9.6±2.8	9.5±2.8	9.4±2.9

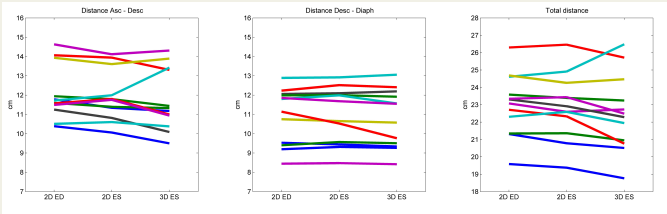

Figure 3: Distance measurements for all individual subjects.
Asc = ascending, Desc = descending, Diaph = diaphragmatic aorta. ED = end-diastole, ES = end-systole.

Discussion/Conclusion

- Differences in aortic path length and corresponding PWV using measurements obtained from 2D-ED and 3D-ES measurements for the ASC-DESC aorta segment were statistically significant.
- This can be explained by the ascending-descending segment showing more **out-of-plane curvature** and **motion** throughout the cardiac cycle than the descending-diaphragmatic segment.
- These results supports using 3D MRI data and selection of the appropriate cardiac phase for accurate assessment of aortic PWV.

References

[1] N. R. Gaddum, J. Alastruey, P. Beerbaum, P. Chowienczyk, and T. Schaeffter, A Technical Assessment of Pulse Wave Velocity Algorithms Applied to Non-invasive Arterial Waveforms, Annals of Biomedical Engineering, Vol. 41, No. 12, December 2013