Experimental Validation of a Software Tool Used for Determining the Pulse Wave Velocity in Blood Vessels from 2D MRI Data

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Introduction

- Cardiovascular diseases are the leading cause of death globally, with arteriosclerosis being a major risk factor [1].
- Early detection of the aorta calcification is possible by measuring the pulse wave velocity (PWV).
- The UKSH-Lübeck developed a software to estimate the PWV from 2D flow MRI-Data, but an independent experimental validation was necessary.
- This work aims to validate the PWV-Software experimentally on a simple in-vitro system.

Material and Methods

• A 4 m long silicone hose (inner diameter: 2 cm, outer Diam. 2,4 cm, Shore 60) was used as a simple vessel model, in order to avoid reflection artifacts and achieve a higher PWV that for a typical Aorta, simulating a worst case scenario.
• The pump system shown in Fig.1 was used to generate physiologically correct pulses (80 ml/stroke, 60 Hz)
• Water was used as the fluid medium (contrast agent Gadovist® added for MRI Measurements).

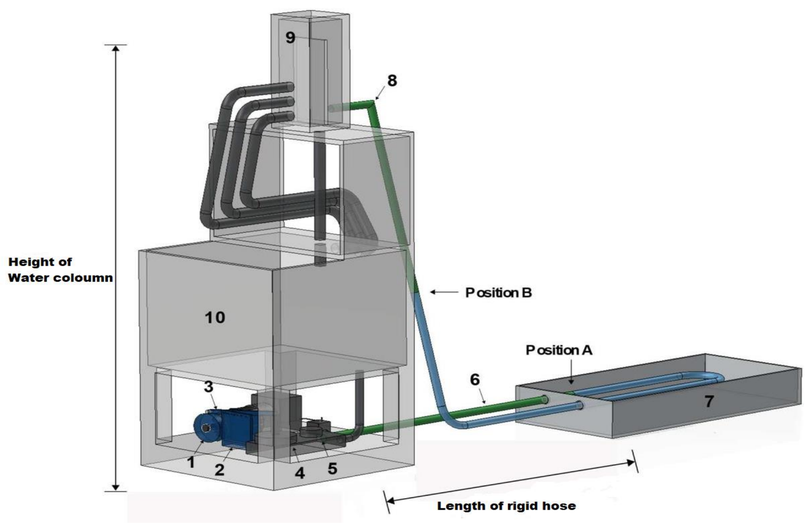

Fig. 1: The set-up for Experimental and MRI measurement. 1) cam, 2) device for adjusting the lever ratio, 3) lever, 4) latex membrane, 5) atrial reservoir, 6) rigid tube (green) with length 4m, 7) Plexiglas box with aortic model (shown in light blue), 8) connecting tube to pump (green), 9) water column, 10) water reservoir.

• The pressure waves were recorded at different positions using pressure sensors from two different manufacturers (WIKA Alexander Wiegand SE & Co. KG, Germany; and Millar Instruments, Inc., USA).
• The PWV was then calculated by using either the Peak-to-peak or Cross-correlation method.

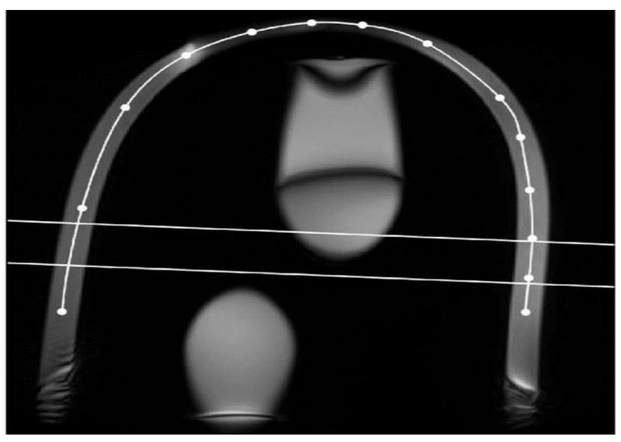

Fig. 2: Representation of the extracted path length from MRI evaluation.

- MRI measurements were performed on a 3T Siemens MRI.
- The PWV was then estimated from the 2D flow MRI data using a Matlab-based software tool [2] and four different algorithms (peak-to-peak (P2P), upstroke-to-upstroke (U2U), foot-to-foot (F2F), and cross-correlation (CC))

Results

- The PWV values for P2P and CC methods were 2555 cm/s and 2337 cm/s for the Wika sensors, and 2360 cm/s and 2362 cm/s for the Millar sensors, respectively.
- The Millar sensors showed a higher repeatability than the WIKA and the calculated PWVs were less sensitive to the used algorithms.

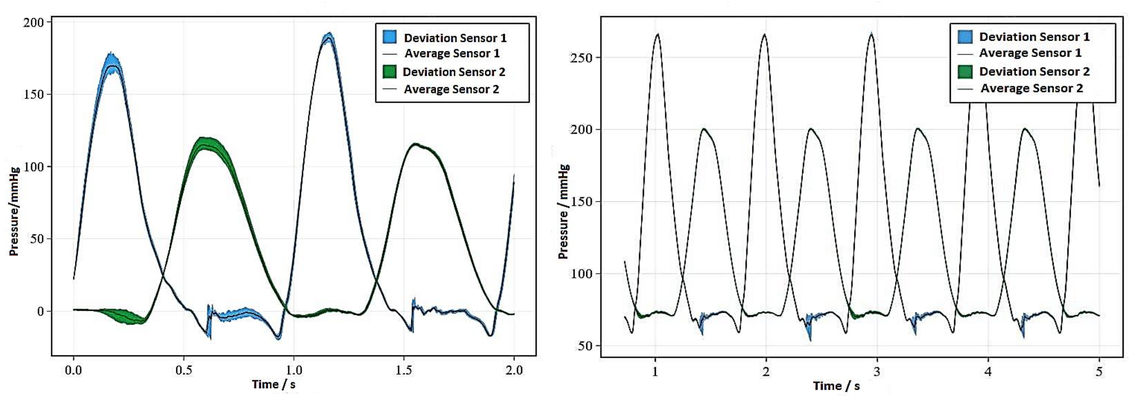

Fig. 3: Pressure curves measured with WIKA sensors (left) and Millar sensors (right), displaying pressure in mmHg plotted against time in seconds.

- The MRI measurement resulted a mean PWV of 1850 cm/s, 1600 cm/s, 2510 cm/s, and 1912 cm/s for P2P, F2F, U2U, and CC methods, respectively.
- The U2U approach showed value closer to the sensor measurements but it needs further validation.

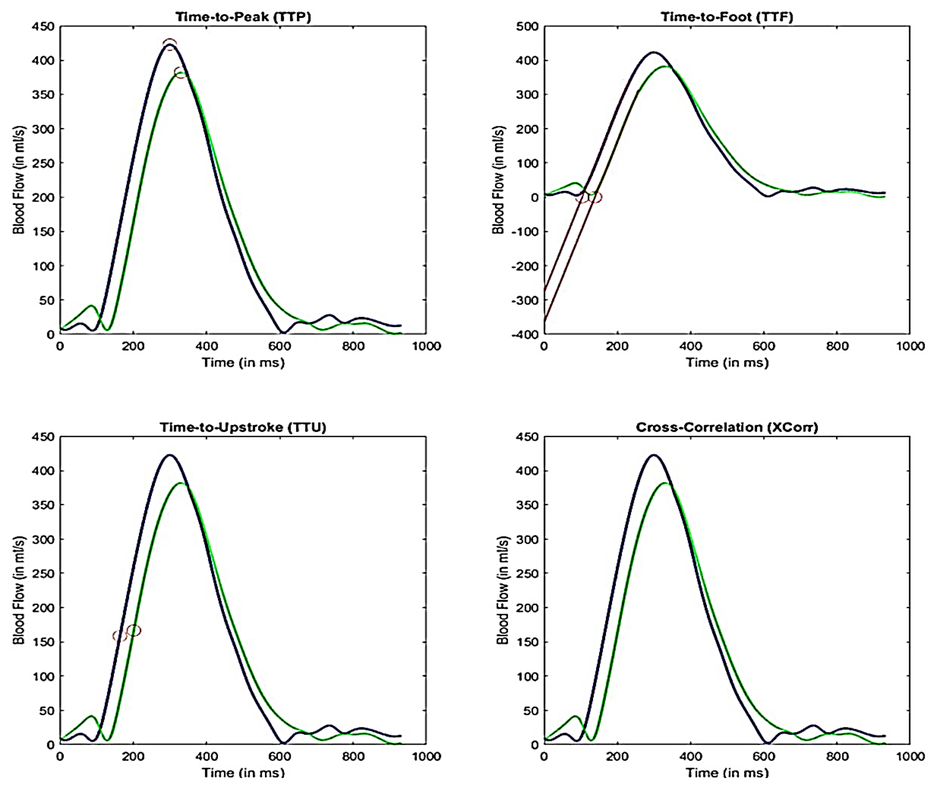

Fig. 4: MRI time shift evaluation for the four algorithms.

- The PWV values obtained from the MRI data were up to 32% lower than those measured with the pressure sensors. This suggest suggests the need for improved MRI data acquisition for reliable PWV values.

Outlook

- Future studies should focus on verifying why the software is not rendering correct PWV.
- Further validation of the MRI data acquisition and evaluation methods is needed.
- The relationship between variable heart rate and possible errors due to imprecise MRI trigger times should also be investigated.

References

[1] Cardiovascular diseases. Available: https://www.who.int/health-topics/cardiovascular-diseases [Last accessed on 2022-11-05].
[2] N. R. Gaddum and et al., A technical assessment of pulse wave velocity algorithms applied to non-invasive arterial waveforms. Annals of biomedical engineering, vol. 41, pp. 2617-2629, 2013.

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