Ultrasound flow assessment in curved vessels: an in-vitro study

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Introduction

Ultrasonic perpendicular velocimetry (UPV) (Fig. 1) allows a simultaneous assessment of axial velocity profile and wall position in straight vessels, enabling an accurate flow estimation [1].

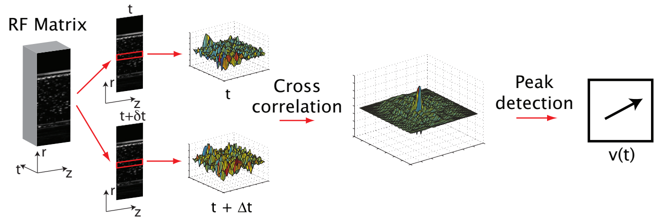

Fig. 1 *Schematical overview of UPV.*

However, in-vivo, most arteries are curved, causing transversal velocity components, which can have an adverse effect on the performance of UPV. Additionally, the presently applied Poiseuille and Womersley approximations offer a poor estimate for the asymmetrical axial velocity distribution, resulting in inaccurate flow estimations.

Objective

Validate UPV for instationary non-Newtonian flow in a curved geometry. Estimate the volume flow from the assessed asymmetric velocity profiles and compare the results with the Poiseuille and Womersley approximations.

Methods

In the experimental setup, a physiologically relevant flow pulse is applied to a curved vessel phantom (Fig. 2). The employed fluid mimics the acoustic and viscoelastic properties of blood.

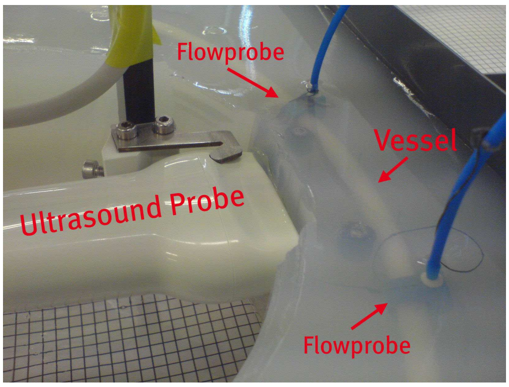

Fig. 2 *Ultrasound probe positioned perpendicular to the vessel.*

The axial velocity distribution is determined by UPV using a linear array probe and subsequently integrated to yield the flow rate [2]. Simultaneously, the flow rate is measured directly. A finite-element CFD model of a rigid walled curved vessel is applied to calculate the time-dependent velocity distribution.

Results

Velocity profiles

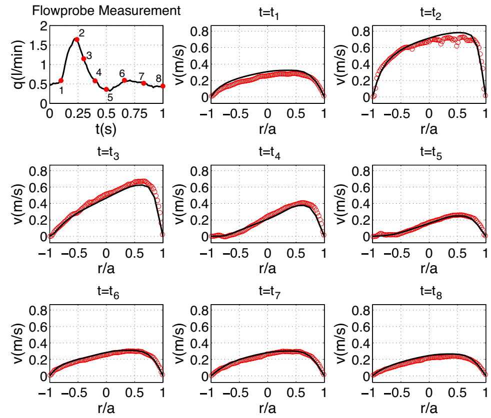

Fig. 3 *Comparison of the UPV measurement (○) and the CFD calculated velocity profiles (—).*

Flow rates

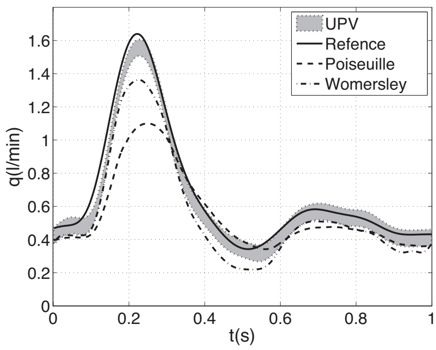

Fig. 4 *Comparison of the reference flow measurement and the UPV, Poiseuille and Womersley based flow approximations.*

For UPV, the average deviation with respect to the reference flow is about 5%, compared to an average deviation of 20% for both the Poiseuille and Womersley approximations.

Conclusions

The UPV method allows an accurate assessment of the axial velocity distribution in a curved vessel. For volume flow estimation it is found that the UPV based flow estimate is far more accurate than the existing Poiseuille and Womersley approximations.

References:

[1] Beulen, B. W. A. M. M. , Rutten, M. C. M. , Brands, P. J. , Vosse, F. N. van de Ultrasound in Med. & Biol., 2008, submitted

[2] Verkaik, A. C. , Beulen, B. W. A. M. M. , Rutten, M. C. M. , Vosse F. N. van de Phys. Fluids, 2008, submitted