Patient specific wave propagation model of the upper limb

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Introduction
Arterial stiffness is an independent predictor of cardiovascular risk at an early stage [1]. The goal of this study is to investigate the feasibility of a new non-invasive method that estimates arterial mechanical properties using a reverse method.

Methods
A set of local ultrasound measurements was obtained from a group of 7 healthy volunteers to provide vessel wall distension (WD), intima media thickness (IMT) and blood volume flow (BVF) at several locations in the upper limb (Fig II). Blood pressure (BP) waveform is estimated from the WD that is stretched using the systolic and diastolic BP. An entire arterial tree model of the arm is built with 36 lumped parameter elements, each consisting of a resistance (R), compliance (C) and inductance (L).

Figure I: Reverse process using Lumped parameter model to estimate arterial mechanical properties

First Input estimation from in-vivo measurements:
BVF at the 1st segment, lumped parameters (R, L and C), end impedance.

Lumped parameter model
Output: Local BP, Local BVF

Comparison between results and measurements:

Correction of the input parameters

An iterative method (Fig I) is used to adjust the arterial parameters until the best fit is obtained between simulated and in-vivo measured pressures and BVF.

Results
The shape of the simulated BVF along the arm is comparable with the in-vivo estimations (Fig III). The global pulse wave velocity obtained from the simulated BP is similar to the estimation from the in-vivo measurements and equal to 11.5 m/s.

Figure III: (A1) Simulated and measured BVF waveforms. (A2) Simulated BP and stretched WD measurements. (B) distances from the wrist of the comparison sites.

Conclusion
The presented reverse method can be used to determine arterial stiffness. Differences between simulated and measured BP and BVF are hypothesized to come from the viscoelasticity of the arterial wall. Hence, future research will focus on a 1-D wave propagation model that incorporates wall viscoelasticity.

References: