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# A wave propagation model to estimate arterial stiffness

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## Introduction

Arterial stiffness,  $S$ , is an independent predictor of cardiovascular risk at an early stage.  $S$  is defined as:

$$S = h \cdot E,$$

with  $h$  the wall thickness and  $E$  the Young modulus.

## Objective

The goal of this study is to investigate the feasibility of a new non-invasive method that estimates  $S$ , using a patient-specific wave propagation model of the upper limb.

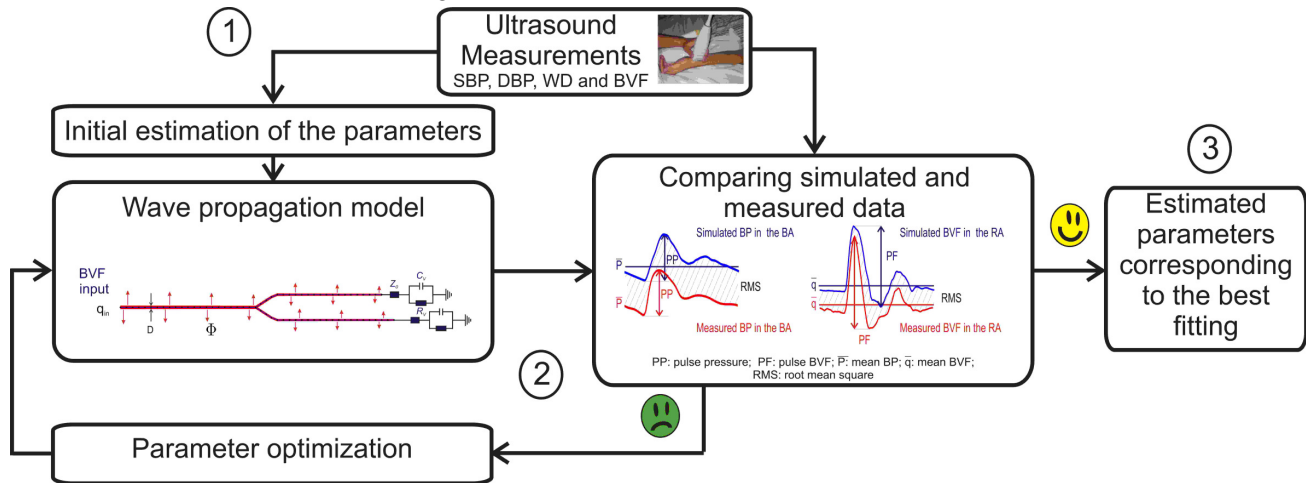


Figure 1: Iterative reverse method based on a patient specific wave propagation model

## Methods

### Clinical measurements

- ❖ Systolic/ diastolic blood pressure (BP) in the brachial artery (BA)
- ❖ Diameter ( $D$ ), wall distension ( $WD$ ) and blood volume flow (BVF) in the BA, radial (RA) and ulnar (UA) artery

### Model parameters estimation

- ❖ Linear elastic model with increasing  $S$  and exponential decay of  $D$ ,

$$S = S_0 \exp(x/L_S), \quad D = D_0 \exp(-x/L_D),$$

with  $x$  the axial coordinate,  $D_0$  and  $S_0$  the initial value,  $L_D$  and  $L_S$  the characteristic decay lengths estimated from the measurements

- ❖  $q_{in}$  : input BVF measured in the BA
- ❖ Winkessel parameters  $Z_0$ ,  $R_v$  and  $C_v$  obtained from a fitting of the BVF and  $WD$  waveform at the RA and UA
- ❖ BVF distributed outflow estimated from the measured time average BVF

### The reverse method

- ❖ Optimized model parameters are obtained using an iterative method, see Fig 1.

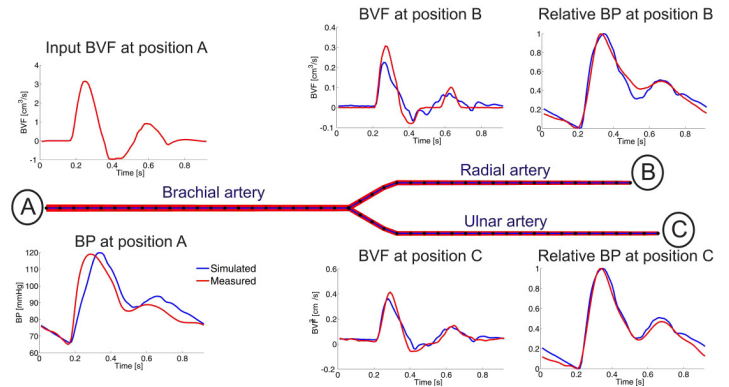


Figure 2: Comparison between the simulated and measured waveforms

## Results

- ❖ Simulated BVF and BP waveform resulting from the iterative method fit the in-vivo estimates at the BA, RA and UA, see Fig 2.
- ❖ Pulse pressure and pulse BVF are the most sensitive to the  $S$  and  $C_v$  respectively.
- ❖  $S$  in the BA, obtained with the model, equals  $0.34 \pm 0.08$  kPa.m. It is 40% lower than the in-vivo estimated  $S$  ( $0.57 \pm 1.3$  kPa.m) from the BA distensibility.

## Conclusion

Patient specific wave propagation models can be used to improve the estimation of in-vivo arterial stiffness.