An extended one-dimensional arterial network for the simulation of pressure and flow in upper and lower limb extremities

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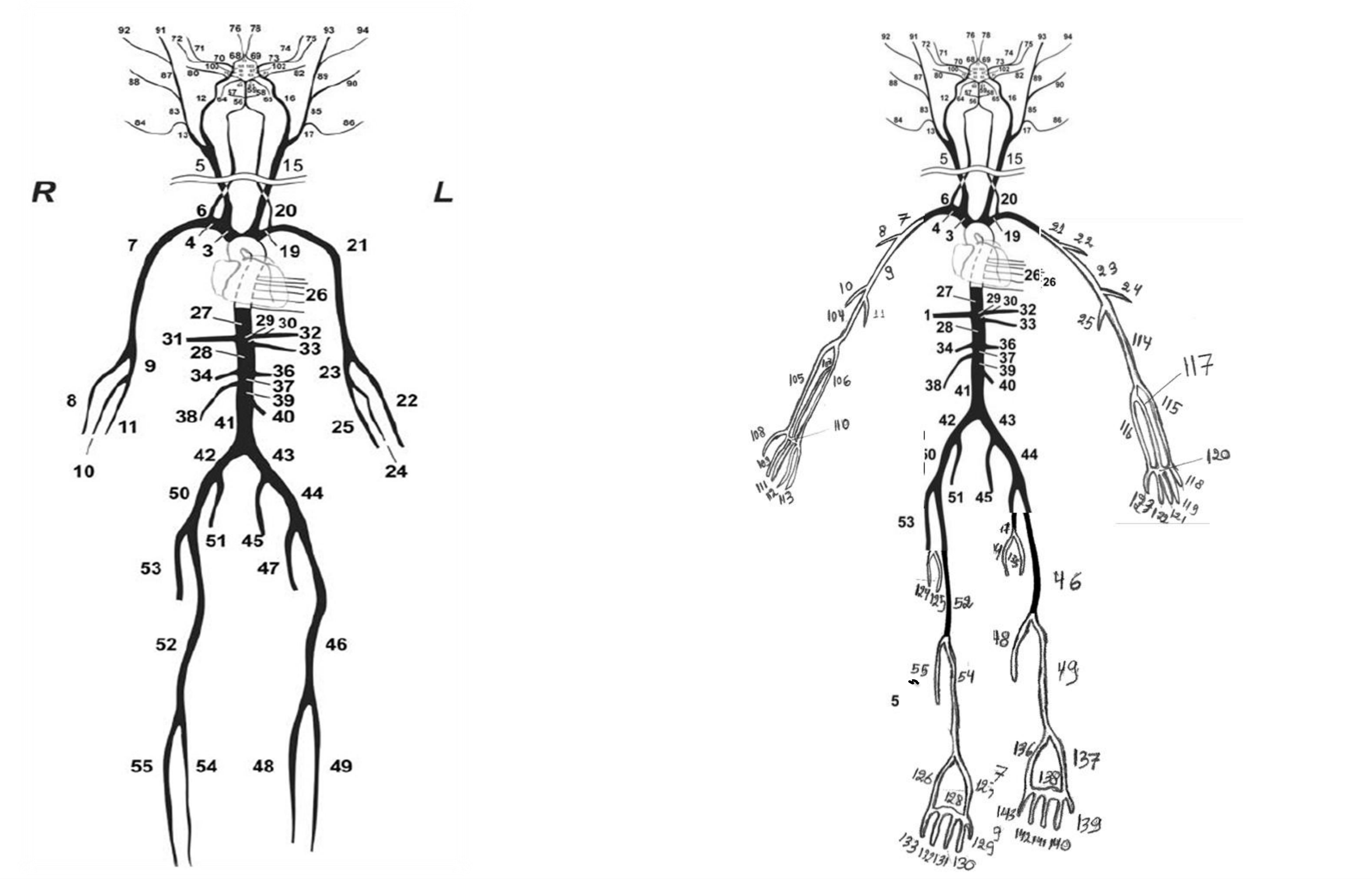
Introduction

Arterial pulse wave velocity and pulse waveform analysis have become an established component of cardiovascular research. As validation and assessment of devices is not always trivial in an in vivo setting, arterial network computer models may be useful for that purpose. It is, however, mandatory that the model includes sufficient detail, especially when analysing peripheral waveforms. The goal is to (i) extend the existing 1D arterial network model (103 segments) of Reymond et al. to a more detailed model (143 segments) including the foot and hand circulation (Radial and Tibial arteries); (ii) use the extending model as testing tool for pOpmètre® (finger – toe pulse wave velocity).

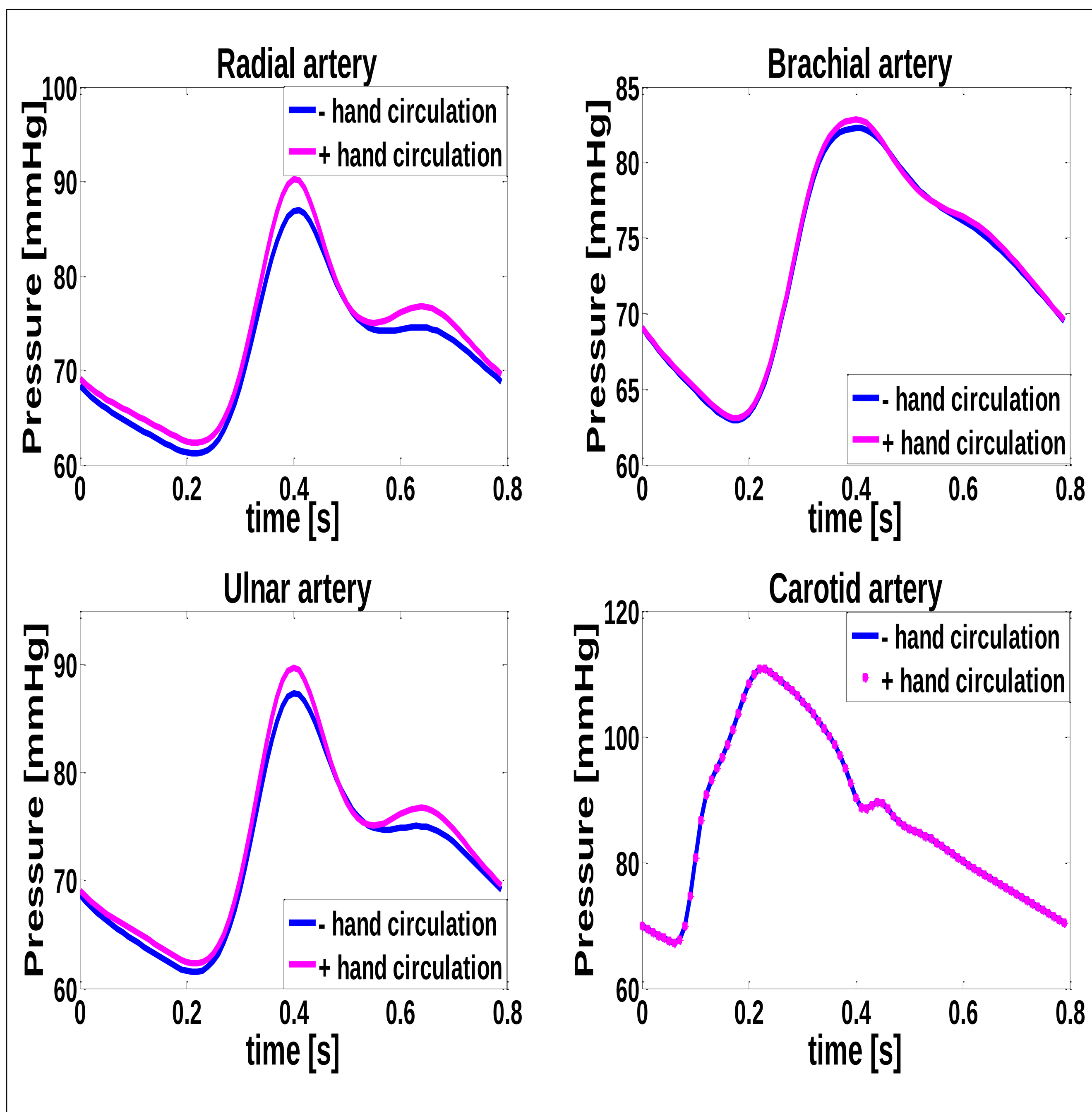
Material and methods

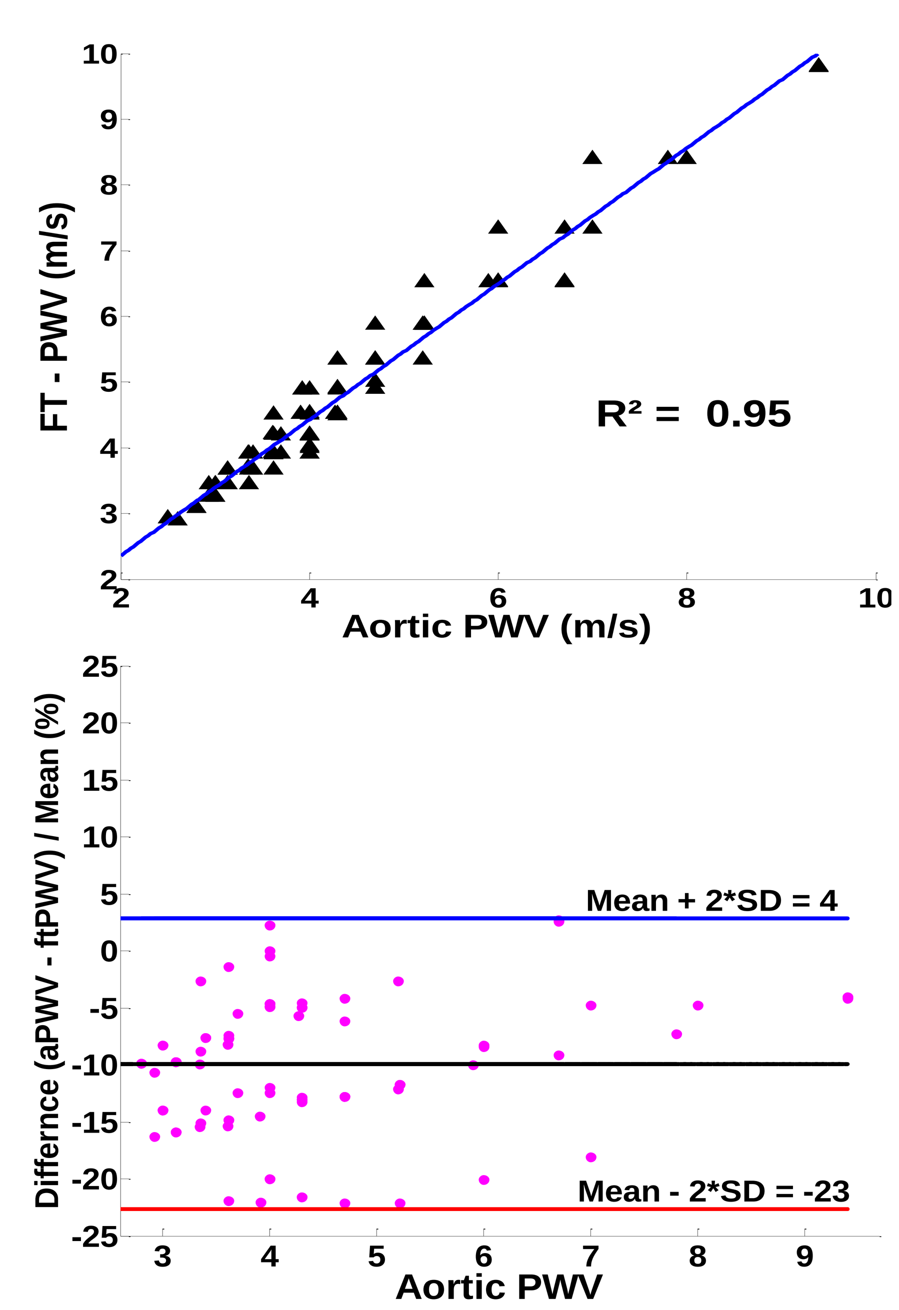
Existing model (103 segments) Extended model (143 segments)

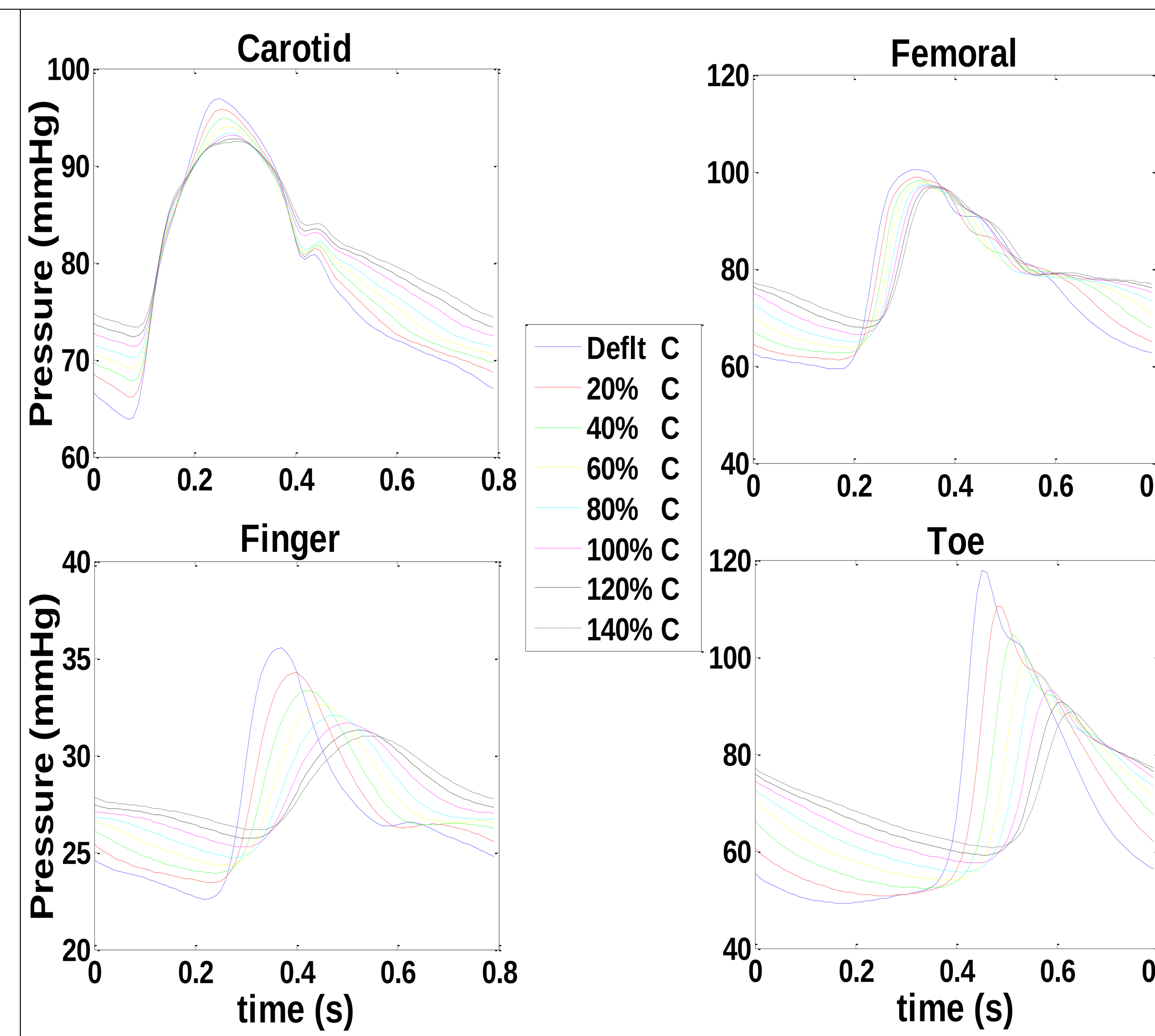


- Simulations were performed for different levels of stiffness of the model.
- Multiplication of the default compliance value of each segment with a constant compliance factor, changing the compliance from its default value to 140% of its default value in steps of 20%.
- Extra simulations were run by changing the default arterial resistance of each terminal windkessel to 80 and 120% of its original value, by changing the duration of a heart cycle to 0.7 and 0.9 s instead of the original 0.8 s and by changing the maximal elastance of the heart model to 1.5 and 3.5 mmHg/ml instead of the default value of 2.5 mmHg/ml.
- A cloud of PWV's for Aortic and finger – toe methods, and these were analyzed using Bland-Altman analysis.

Results







- Comparison of simulations with and without detailed hand and foot circulation demonstrate differences in waveform morphology.
- The completed model predicts pressure and flow waves in the hand and foot arteries, which are in good qualitative agreement with the published in-vivo measurements.
- The correlation between ftPWV and aPWV was good and significant ($R^2 = 0.95$). The Bland and Altman analysis, mean difference was 0.4 m/s, classifying the ftPWV as good agreement with reference method.

Conclusion

The extended model yields realistic pressure and flow waveforms in arteries of the hand and the foot. After full validation, the extended model used to assess the performance of diagnostic and screening devices relying on peripheral hemodynamics signals, the pOpmètre® (finger – toe PWV), where the correlation with the refernce method showed a good agreement.