Age-specific Topology Minimization in a One-dimensional Model Describing Carotid Haemodynamics

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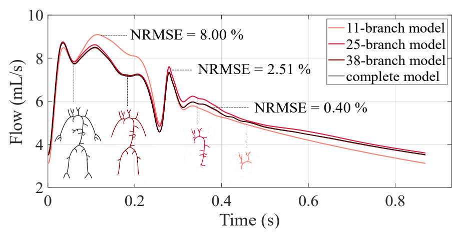
Background: Personalized one-dimensional (1D) haemodynamic models have the potential to guide patient-specific clinical decisions through an improved interpretation of carotid ultrasound (cUS) waveforms. 1D topologies may include up to thousands of arteries. However, personalized models are parameterized using in-vivo measurements (e.g., cUS velocity and diameter, arterial pressure, heart rate), thus, available data are typically limited as compared to the number of input parameters required to describe these models (e.g., vessel lengths, diameters, compliances). It is, therefore, necessary to determine the lowest level of topological complexity required to accurately predict waveforms without loss of features of interest, while minimizing the uncertainty introduced by over-parametrization. **Methods:** We investigated the minimal topology necessary to predict cUS flow waveforms in virtual subjects of different ages ranging from 10 to 80 years old. Starting from a clinically validated 55-branch baseline topology, we progressively lumped 1D segments into equivalent Windkessel RCR models, using prior knowledge of model output sensitivity to input parameters and standard in-vivo measurements availability to guide the truncation process. In our models, pulsatile haemodynamics was simulated using the 1D blood flow equations with an elastic tube law using the NEKTAR++ Pulse Wave Solver. **Results:** Simulated carotid waveforms for three levels of model reduction, and normalized root-mean-square errors (NRMSE) compared to the prediction by the complete model, are shown in the Figure for a 45-year-old subject. We obtained age-specific minimum topologies, considering an NRMSE threshold of 3% on the prediction of carotid flow waveforms. Preliminary results show that the initial set of model parameters can be reduced by more than one third, without impacting key features of the carotid waveform. **Conclusions:** This work sets the basis for the generation of patient-specific 1D models for the study of carotid haemodynamics in subjects of different ages.



Carotid flow waveforms as predicted by 3 reduced models in an adult virtual subject.