Multiscale model of the cardiovascular system: application to pathological and altered acceleration conditions

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In the current literature, various models of the human circulation have been developed, to contribute to both physiology understanding and medical advances[1]. In this context, we propose a physically-based multiscale mathematical model of the entire cardiovascular system[2], schematically reported in Fig. 1a.

The arterial network is characterised through a 1D model, which allows to describe the wave propagation and reflection (this latter is due to vascular geometric and mechanical discontinuities) proper of the largest vessels, the anisotropic non-linear viscoelastic behaviour of the arterial walls, as well as the vessel tapering and branching. The model is based on the mass and momentum balance equations, integrated over the arterial transverse area, and is written under a series of assumptions: axisymmetric vessel geometry and flow field, laminar flow, longitudinally tethered arterial walls, homogeneous and Newtonian blood. The remaining part of the circulatory system (the capillary units, the venous return, the heart and pulmonary circulations) is formulated according to the Windkessel approach[1] and consists of a suitable combination of resistances, inductances and compliances, representing the viscous, inertial and elastic effects, respectively. Concerning the heart modelling, both the atrial and ventricular contractions are considered and the dynamics of the four cardiac valves are accurately reproduced, according to the forces applied on the valve leaflets. A short-term autoregulation system is also added, to adjust the heart rate, the cardiac contractility and the vascular tone with respect to the arterial pressure alterations.

The present model is exploited to evaluate the pressure wave patterns (Fig. 1b) in case of cardiac arrhythmias and to analyse the acceleration effects on the global hemodynamics during human spaceflight.

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[1] Shi et al., *Biomed. Eng. Online* **10**, 33 (2011).

[2] Blanco et al., *Med. Eng. Phys.* **35**, 652 (2013).

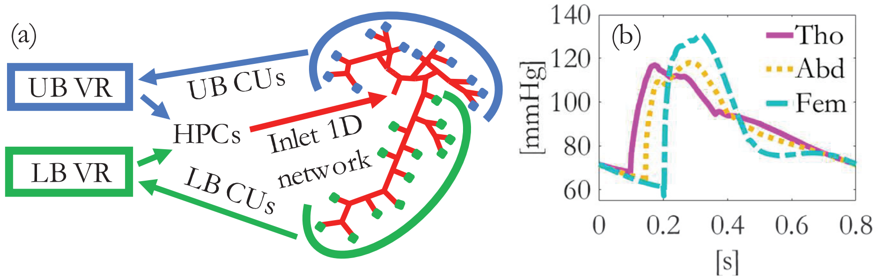

Figure 1: (a) Model scheme (UB/LB CUs: upper/lower body capillary units, VR: venous return, HPCs: heart and pulmonary circulations, 1D network: arterial domain). (b) Thoracic (Tho), abdominal (Abd) and femoral (Fem) arterial pressure records in normal sinus rhythm.