A comprehensive multiscale model of the cardiovascular system

Caterina Gallo[1], Luca Ridolfi[2], Stefania Scarsoglio[1]
[1] *DIMEAS/* [2] *DIATI, Politecnico di Torino, 10129 Torino, Italy*
E-mail:caterina.gallo@polito.it,luca.ridolfi@polito.it,stefania.scarsoglio@polito.it

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Numerous mathematical models of the cardiovascular system have been proposed [1, 2], both to further explore the physiological behaviour of circulation and support medical developments. In this context, we present a closed-loop multiscale model, which has the advantage to integrate into a single framework the fundamental characteristics of the cardiovascular system: the arterial wave propagation, the complex dynamics of cardiac valves, the short-term baroreflex mechanism, a well-organised structure of micro-circulation groups and venous return, and the unstressed volumes. The main goal of this work is to effectively simulate each portion of the cardiovascular system.

Large-medium arteries are described through the 1D mass and momentum equations, considering the vascular tapering and branching, and the anisotropic non-linear viscoelastic behaviour of the arterial walls [3]. The rest of circulation is represented through a proper combination of resistances, compliances and inductances, standing for the viscous, elastic and inertial effects, respectively. Both the contractility of the cardiac chambers and the non-ideal behaviour of cardiac valves are modelled. A short-term baroreflex model is included to guarantee homeostasis.

As shown in Fig.1a, pressure waves correctly propagate along the arterial tree, with systolic pressures increasing, diastolic pressures decreasing, pressure signals delaying and steepening along the aorta. Valvular flow rates in Fig.1b are also in agreement with literature data, with reverse flows as valves close. This model well mimics the expected hemodynamics and can be used for different applications (e.g., cardiac pathologies, orthostatic variations, exercise conditions, etc...).

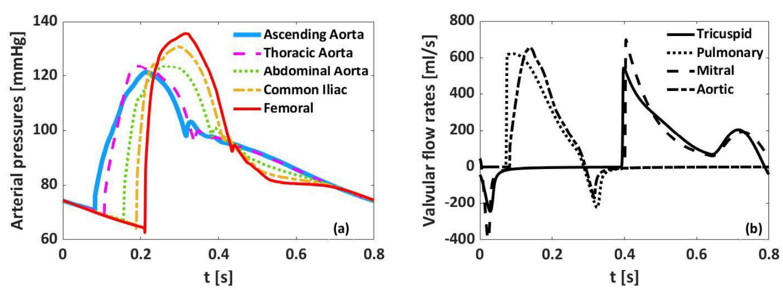

Figure 1: Pressures along the arterial tree (a) and valvular flow rates (b) at 75 bpm.

References

[1] *Shi, Y., Lawford, P., and Hose, R., "Review of zero-D and 1-D models of blood flow in the cardiovascular system", Biomed. Eng. Online,* **10**, *33 (2011).*

[2] *Blanco, P.J., and Feijóo, R.A., "A dimensionally-heterogeneous closed-loop model for the cardiovascular system and its applications", Med. Eng. Phys.,* **35**, *652–667 (2013).*

[3] *Scarsoglio, S., Gallo, C., and Ridolfi, L., "Effects of atrial fibrillation on the arterial fluid dynamics: a modelling perspective", Meccanica,* **53**, *3251-3267 (2018).*