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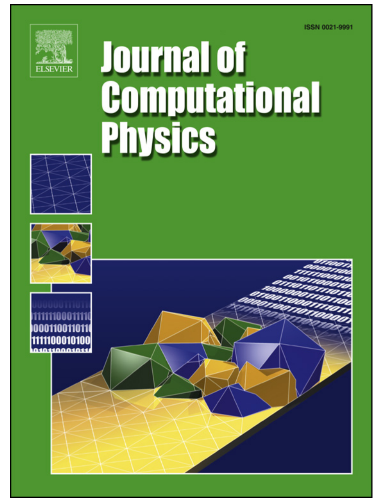

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Consistent treatment of viscoelastic effects at junctions in one-dimensional blood flow models

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Abstract

While the numerical discretization of one-dimensional blood flow models for vessels with viscoelastic wall properties is widely established, there is still no clear approach on how to couple one-dimensional segments that compose a network of viscoelastic vessels. In particular for Voigt-type viscoelastic models, assumptions with regard to boundary conditions have to be made, which normally result in neglecting the viscoelastic effect at the edge of vessels. Here we propose a coupling strategy that takes advantage of a hyperbolic reformulation of the original model and the inherent information of the resulting system. We show that applying proper coupling conditions is fundamental for preserving the physical coherence and numerical accuracy of the solution in both academic and physiologically relevant cases.

Keywords: Finite volume schemes, viscoelasticity, junctions, one-dimensional blood flow.

1. Introduction

The viscoelastic behavior of arterial and venous walls is well-known [1, 2, 3]. It has an impact on fundamental hemodynamic characteristics of the cardiovascular system [4] and plays a determinant role in setting the functional level of the cardiovascular system under physiological and, especially, under pathological conditions such as hypertension [5].

Among the many theoretical frameworks developed by applied mathematicians and biomedical engineers to study the cardiovascular system, one-dimensional blood flow models constitute a relevant tool which has been utilized since the late 70s to gain understanding on arterial functioning [6, 7, 8, 9]. More recent contributions to the development of one-dimensional models for the arterial and venous systems can be found in [10, 11, 12, 13, 14, 15, 16]. These models have been used to study a number of pathologies, some examples can be found in [17, 18, 19, 20, 21, 22, 23, 24]. Moreover, the output of such models has been validated versus *in vitro* models [25] and *in vivo* measurements [10, 14].

It is well known that blood flow in large to medium vessels is a convection-dominated process. Therefore most practitioners neglect viscoelasticity of vessel walls in their one-dimensional models. The resulting model is then essentially a hyperbolic system of partial differential equations and its numerical approximation is ruled by well-established strategies on this field. However, when certain models of vessel wall viscoelasticity are used [12, 16, 25, 26, 27], a second order

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