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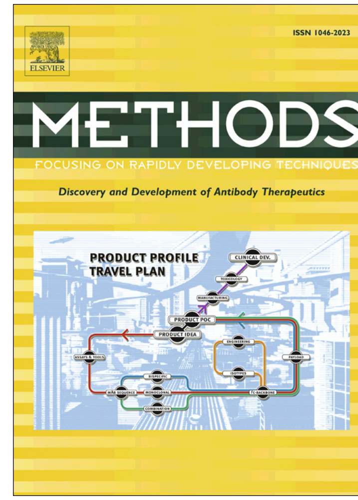

Live imaging and modeling for shear stress quantification in the embryonic zebrafish heart

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Live imaging and modeling for shear stress quantification in the embryonic zebrafish heart

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Abstract

Hemodynamic shear stress is sensed by the endocardial cells composing the inner cell layer of the heart, and plays a major role in cardiac morphogenesis. Yet, the underlying hemodynamics and the associated mechanical stimuli experienced by endocardial cells remains poorly understood. Progress in the field has been hampered by the need for high temporal resolution imaging allowing the flow profiles generated in the beating heart to be resolved. To fill this gap, we propose a method to analyze the wall dynamics, the flow field, and the wall shear stress of the developing zebrafish heart. This method combines live confocal imaging and computational fluid dynamics to overcome difficulties related to live imaging of blood flow in the developing heart. To provide an example of the applicability of the method, we discuss the hemodynamic frequency content sensed by endocardial cells at the onset of valve formation, and how the fundamental frequency of the wall shear stress represents a unique mechanical cue to endocardial, heart-valve precursors.
Keywords: embryonic heart, heart dynamics, zebrafish, hemodynamic harmonics, method of fundamental solutions, stokes flow, atherosclerosis, shear stress

1. Introduction

The forces generated by the blood flow in the heart can be sensed by endocardial cells and modulate the early stages of heart development [1, 2]: From chamber formation (ballooning) to valve development [3] and trabeculation [4, 5]. Cilia and calcium channels like Piezo1 [6, 7] in blood vessels, and Tprv4 and Trpp2 in the heart [8] have been implicated in mediating mechanotransduction pathways in the developing cardiovascular system. The transduced mechanical cues have been mainly associated to shear stress amplitude and to its frequency content (i.e. to how shear stress changes over time) [9, 8]. Yet, both the mechanotransduction pathways and the transduced mechanical stimuli are poorly understood.

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