Investigation of Lymphatic Valve and Vessel Operation via Computational Modeling

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The lymphatic system plays a vital role in the circulatory and immune systems with a range of important functions such as transport of interstitial fluid, fatty acid, and immune cells. The lymphatic system circulates throughout the body via collecting lymphatics, which is composed of a chain of lymphatic vessels and flexible valves composed of two leaflets. This allows the lymphatic system to pump lymph against adverse pressure gradient and prevent backflow. Despite the significance of the lymphatic system, the influence of many valve and vessel properties to the lymphatic dysfunction is not well understood. This is especially alarming considering that millions worldwide are affected by lymphatic dysfunction such as lymphedema without any cure [1]. Furthermore, experimental data of the lymphatic vessels and especially lymphatic valves is limited, where some data like mechanical properties of lymphatic valves is almost nonexistent.

![Figure 1. A diagram of a chain of lymphatic vessels and valves.](image1)

In this work, we present a fully-coupled fluid-solid, three-dimensional computational model to investigate various vessel and valve parameters thought to affect the lymphatic function and the effects of these parameters to lymphatic system performance. A lattice Boltzmann model is used to simulate lymph flow, and a lattice spring model modified for large membrane deformation is utilized for solid deformation [2]. Lymphatic system’s effectiveness in areas such as resistance minimization, backflow prevention, and viscoelastic response under varied lymphatic vessel and valve geometries and mechanical properties is investigated.

![Figure 2. An isometric view of the computational model](image2)

Results suggest that lymphatic valves play a significant role in lymphatic system’s effectiveness. Particularly, the lymphatic valve’s effectiveness is optimized when valve’s aspect ratio and bending stiffness are low, as long as the valve can still properly close to prevent backflow. The simulation also demonstrates the valve’s delayed response to the vessel contraction, which is also suggested experimentally [3]. In conclusion, the results highlight lymphatic valve’s role on the performance of the lymphatic system. The results also provide a greater understanding on how certain lymphatic pathologies such as valve defects in primary lymphedema can lead to lymphatic dysfunction [4], [5].

Reference

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