Fluid Pumping and Mass Transfer in the Lymphatic System

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The lymphatic system has many recognized important roles in normal physiology and in a variety of disease conditions. In addition to returning fluid from interstitial tissue spaces to the blood circulation, it also serves as an important transport route for immune cells. Lymph nodes are important sites for cellular interactions involved in immunity, inflammation and fluid balance. Transport phenomena and/or breakdowns in lymphatic system performance are crucial, or at least involved in, cardiovascular diseases, cancer, obesity and injury resolution. Despite the importance in so many causes of death and disability, little is actually known about transport mechanisms in this obscure system.

We have developed models of lymphatic system pumping based on a multiscale approach, combined with a unique experimental skill set. While our results have revealed much about lymphatic transport, they have also clearly identified two physical properties of lymphatic vessel behavior that are both crucial for determining pumping, and for which experimental data are extremely difficult to obtain. The first is the resistance of lymphatic valves to both forward and reverse flows, and how they switch from the closed to the open position and back. The second is the unique abilities of lymphatic muscle cells (LMC) to contract over a wide range of vessel diameters. Our current experimental and modeling work is focused on quantifying these parameters better.

We are also beginning to incorporate important fluid flow phenomena in lymph nodes. These are highly compartmentalized structures in which leukocytes process antigens, foreign bodies and tumor cells. There are also specialized direct communication ports with the blood circulation in which fluid and cells can traverse in either direction.

The results of this research will include the most advanced model of lymphatic transport and function to date, the ability to predict the effects of interventional procedures, and the optimization of those procedures for the benefit of the numerous patients suffering from lymphatic associated diseases.