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Optimal flow patterns in branching lymphatic vessels

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Understanding lymphatic development is clinically relevant in applications from the viability of embryos, to chronic inflammation, to cancer metastasis. I specifically quantify the branching structure of developing lymphatic vessels and numerically solve for the flow through these vessels. Branching in arterial development is understood to consistently follow Murray's Law, which states that the cube of the radius of a parent vessel is equal to the sum of the cubes of the radii of the daughter vessels, thus minimizing the cost and maintenance of fluid transport. I have found that an optimization law for lymphatic vessels is less straightforward. The derivation of Murray's Law includes several assumptions, such as vessels of constant diameter filled with a Newtonian fluid, fully developed and unidirectional flow, and long segments between junctions. Several of these necessary assumptions do not hold for lymphatic capillaries. The relationship between the parent and daughter vessels is upheld through a strictly additive rule, and the daughter vessels are smaller than would be predicted by the hypothesized radius-cubed law. The variability in vessel diameter and potential for bidirectional flow suggest a different optimization strategy based on the geometry and function of the system. In this presentation, the immersed boundary method is used to numerically solve the equations of fluid flow through branching vessels. The results are then used to test the assumptions of Murray's Law as well as several hypotheses regarding branching geometry.

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