Multi-scale models of the vascular network supplying tumors

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Abstract

Blood flow to tumors plays a vital role in tumor growth, metastasis, as well as cancer treatment. It is commonly believed that angiogenesis is a critical step in the formation of a malignancy. Through angiogenesis, a cancerous tumor that is size limited by the lack of blood vessels is able to rapidly increase in size. There is a pressing need for more detailed, patient specific models of the circulatory system of patients undergoing drug therapy. However, from a technical point of view there are several challenges. One of these challenges is the large number of vessels feeding the cancer tissue, which is dramatically increased by angiogenesis. In addition, the tumor vessels are geometrically more disorganized than normal vessels. It is currently not possible to model their full three-dimensional structure using current computational resources.

In this talk, we discuss the potential application of 1D models to tumor circulation as an alternative to full three-dimensional modeling. In particular, the subject of 1D models as applied to vascular networks is discussed. The use of 1D models has intensified recently, including clinical applications to medical problems such as a thoraco-thoraco aortic bypasses and coronary arterial networks. In recent work, we have generalized the classical 1D models to provide better estimates for wall shear stress and better predictions of the pressure waveform for pulsatile flows. These generalizations are motivated by an asymptotic solution for steady flow in slender bodies as well as the analytical solution for fully developed pulsatile flow in straight vessels with constant circular cross section. The resulting generalized 1D equations are shown to provide a significantly better match with the NSE in benchmark problems chosen for their relevance to arterial flows.