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Fluid-Structure Interaction in Arterial Network and Implications for Blood Pressure Measurement– A Numerical Study

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ABSTRACT

Central blood pressure, i.e., the blood pressure near the heart, is an important physiological indicator of the cardiovascular function of a patient. However, direct measurement of this quantity is rarely carried out due to the invasive nature of the procedure. Instead, blood pressure at the arm (brachial artery) measured through an inflatable cuff is commonly used to represent or estimate the central blood pressure. On the other hand, the aortic pressure propagates downstream in the form of pulse waves, which have to pass through a complex and compliant vascular network to reach the brachial artery. Therefore, the efficacy of cuff-measured pressure is still under clinical debate, which is partially stemmed from a lack of understand of the physics implicated in the propagation process. In this study, we theoretically explore the effectiveness of the cuff measurement in evaluating central blood pressure through fluid-structure interaction simulations. We employ a patient-specific arterial tree in the upper limb and apply physiologically-accurate boundary conditions, including inlet flow rate and three-element Windkessel outlet conditions. The fluid-structure interaction is modeled using the coupled momentum method. The spatial variation of the material property and thickness of the vessel wall is taken into consideration, and we investigate the influence of several popular vascular material models on the pressure wave propagation. We also develop an analytical model to provide further insights into the fluid-structure interaction. The results show that the vascular diameter variation and the choice of vascular material model have a great impact on the pulse wave propagation; the analytical model is in great agreement with the numerical results and can be used to calibrate the difference between the cuff-measured pressure and the central blood pressure. This study can potentially provide a theoretical basis for the development of more accurate non-invasive blood pressure measurement methods.

KEYWORDS

Hemodynamics; fluid-structure interaction; computational fluid dynamics; blood pressure

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