Comment on "Radial and longitudinal motion of the arterial wall: Their relation to pulsatile pressure and flow in the artery"

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Most researchers derived the arterial pressure-wave equation by taking the axial blood flow as the major mechanism and assumed the flow motion was governed by the Navier-Stokes equation. However, only realistic hemodynamic theory can help to develop method for future healthcare. Here, we pointed out a different rigorous hemodynamic model that explained many physiological facts. Our previous work started directly from Newton's law by deriving the radial and the axial momentum equations of the elastic arterial wall system and of the enclosed blood system, with the contact forces between the two systems being counted explicitly. Our model has some important applications in future healthcare, such as providing a basis for studying the collective behavior of the cardiovascular system and developing quantitative methods for disease prevention and diagnosis.

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From our previous study on the equations of motion for the cardiovascular system, we concluded that developing quantitative pulse diagnosis with realistic hemodynamic theory can pave a way for future personalized healthcare [1]. The paper "Radial and longitudinal motion of the arterial wall: Their relation to pulsatile pressure and flow in the artery" also made effort to study this important mechanism in physiological system [2]. Here, I pointed out some relevant but different basic concepts that might help future studies.

In 1755, the Euler equation was first constructed to describe the blood flow in a tube. Since then, almost all of the physical and mathematical modeling of pulse-wave propagation in artery was constructed based on general fluid-dynamical principles by considering the conservation of mass and the Navier-Stokes (NS) equations of the fluid system. The elastic vessel was taken into account as the boundary conditions for the enclosed fluid. The NS equation was also adopted by the authors of Phys. Rev. E 98, 032402 (2018) and of the references cited therein [2]. Due to the existing arterial pressure wave, the vessel is performing a distributed radial oscillatory motion which can be known only after the pressure-wave problem has been solved. Hence utilizing the NS equations or their modified forms is a complicated method to study the blood motion in arterial system.

To avoid dealing with the interacting forces between the blood system and the elastic vessel, we first applied Newton's law by taking the vessel and the fluid together as one system. We have derived a pressure-wave equation, which proposes that the energy transportation in the main arterial system is primarily via the transverse vibration motion of the elastic wall and a thin layer of adherent blood. The final equation indicates that the longitudinal stress is essential [3], and many important physiological phenomena can be explained.

In order to elucidate the distinction of our results with the established dynamic equations in literature, we then followed the common approaches by taking the fluid and the vessel as two separate systems. However, interaction of the two systems was not treated merely as the mutual boundary conditions but was counted directly with the mutual contact forces. Furthermore, the momentum equations of the two systems were tackled in both the axial and the radial directions. An ordinary pressure-radius (PR) wave equation, similar to our previous pressure-wave equation, was directly obtained by adding the two resultant radial momentum equations of the vessel system and of the enclosed blood system. [4]

The PR wave equation, similar to a transverse vibrational string with large longitudinal tension [3], has low dissipation character and is the primary realistic wave equation [5] that can be utilized as a starting equation and be analyzed by the eigenwave modes of the whole aortic system [6] to develop quantitative methods for studding the cardiovascular system in a collective manner.

It was reported that axial fluid kinetic power takes only 2 to 7% of the total ventricular output [7]. After the PR wave equation has been solved, the axial flow motion of the blood can be obtained by the equation of continuity of the blood mass or from the resultant generalized axial momentum equations for the blood system, rather than from the Navier-Stokes equation.

In vivo, the arterial vessel has large longitudinal tension and is strongly constrained in the axial direction; hence, the axial motion of the wall is negligibly small [8,9] for the first-order consideration. It can be considered only after the pressure-wave equation and the axial flow motion have been solved.

By taking many physiological facts into account, we constructed a multirank model to link the whole cardiovascular system together [10]. The model provides a scientific basis for exploring how the collective behavior of the circulatory system reflects in the arterial pulse at any site of the artery and how the cardiovascular system achieves its high efficiency as a compound irrigation device through arterial resonance [1,11,12].

I hope that this realistic theoretical model will be useful to physicists who study hemodynamics.

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