Mathematical modeling of the arterial stiffness: solitons-based model versus fractional order model

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In recent decades, arterial models have proved to be extremely useful and effective in unraveling cardiovascular diseases, in medical intervention planning in disease treatment and monitoring, and in the design and testing of medical devices. Besides, arterial models have shown great potential for noninvasive evaluation of physiological parameters that are not directly accessible, such as arterial compliance and stiffness. Arterial stiffness is a key risk factor and its accurate clinical assessment is crucial. Various clinical and experimental research studies have been proposed to quantify the arterial stiffness, and several arterial compliance surrogates have been developed. However, most of them suffers from limitations in the measurement procedure and accuracy.

In this talk, I will present two of our recent mathematical models of the arterial stiffness. The first model is based on the concept of solitons' waves, solutions of the Korteweg-de Vries (KdV) equation. The KdV equation has been proposed as a model of the blood pressure. The soliton's characteristics are then used to extract the pulse wave velocity from a single non-invasive blood pressure measurement.

The second model relies on the concept of fractional derivatives. A fractional differential equation is proposed as a model for the arterial hemodynamics where the fractional derivative is correlated to the viscoelasticity of the arteries, and hence provided a new biomarker for the arterial stiffness from noninvasive blood pressure measurements.

In both cases, the mathematical challenges, advantages, limitations, and validation results will be presented, with a particular focus on the calibration of the fractional model.