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A NOVEL MODEL FOR EXPLANATION THE REGULAR AND CHAOTIC DYNAMICS IN ARTERIAL BLOOD FLOW

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Long measurements of the blood pressure $P(t)$ and flow rate $Q(t)$ oscillations in arteries revealed prevalent regular dynamics in young healthy volunteers and frequent nonlinear chaotic dynamics in elderly [1, 2]. The heart rate variability, nonlinear properties of the blood vessel wall and turbulent blood flow were discussed for explanation the chaotic behavior. As it was shown in [3], the chaotic dynamics in elderly may appear in the distant parts of the cardiovascular system (CVS), while in the central arteries the flow is quasi-regular.

In this paper the broad band noise with no distinct peaks (1/f noise) is found in the power spectrum of the $P(t)$ and $Q(t)$ time series. The maximal Lyapunov exponents are found to be negative in the central aorta and positive in the upper and lower extremities. A model of the CVS as a series connection of n viscoelastic chambers is proposed. It is shown the pressure oscillations in the chamber are governed by the nonlinear n-th order ODE

$$\sum_{j=1}^{n} A_j \frac{d^j P}{dt^J} + A_0 P = \sum_{j=1}^{n-1} B_j \frac{d^j Q}{dt^J} + A_0 Q, \tag{1}$$

where A_j, B_j are nonlinear functions of the material parameters and resistivities $\{Z_i(P_i)\}_{j=1}^n$ of the chambers.

Solution of (1) has been studied at wide variations of the viscoelastic properties of the chambers. It is shown the abnormal high compliance of the distant chambers may lead to varying time delays between the responds of the chambers to the pressure variations and, thus, to the chaotic dynamics. Direct applications to the medical diagnostics of deep vein thrombosis and chronic arterial insufficiency in the lower extremities are discussed.

References

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