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Flow distribution and wave propagation in arterial systems with anastomoses

N. N. KIZILOVA and R. P. SECHIN

Department of Theoretical Mechanics, Kharkov National University, Ukraine

1. Introduction

Blood flow and wave propagation in the systems of compliant tubes filled with a fluid have been examined as a model of the systemic circulation and the intraorgan arterial networks have been modeled as Windkessel elements (Westerhof 1973) or regular tree-like branching structures (Olufsen 2001). Real intraorgan vasculatures possess some geometrical regularity and can be modeled as fractal-like trees. Nevertheless blood flow in the real beds and their self-similar models have some differences. Moreover real vasculatures often have anastomoses which provide additional pathways for blood flow and wave propagation and reflection. Arterial beds in the small and large intestine, in stomach and limbs have arterial anastomoses that influence input admittance spectra of the beds in comparison with the tree-like systems (Kizilova 2003).

2. Materials and methods

Geometry and topology of the loops which are formed by extraorgan arteries of the large intestine have been examined in eight corpses. The terminal arterial branches of the loops which provide blood delivery to the intestine are embedded into the tissues. The correspondent models as the systems of straight viscoelastic tubes terminated by three-element Windkessels Z_t have been investigated (figure 1). Blood pressure at the outlet of each Windkessel has been taken as a constant capillary pressure P_k. Pressure waveforms P_a in the upper and lower mesenteric arteries have been taken from *in vivo* measurements.

Poiseuille blood flow in each tube has been considered as a model of the steady blood flow. The linear algebraic system for the flows in the tubes and the pressures in the nodes has been obtained from the pressure and flow continuity conditions in the bifurcations. Wave propagation in the system has been described by the Womersley's model in the form:

$$P_j(t,x_j) = P_j^0 e^{i\omega t}(e^{-i\omega x_j/c_j} + \Gamma_j e^{i\omega(x_j-2L_j)/c_j})$$

$$Q_j(t,x_j) = Y_j^0 P_j^0 e^{i\omega t}\left(e^{-i\omega x_j/c_j} - \Gamma_j e^{i\omega(x_j-2L_j)/c_j}\right)$$

where P_j, Q_j are pressure and flow amplitudes, c_j is the wave velocity, $P_j^0 = P_j(t,0)$, $Y_j^0$is the characteristic admittance, Γ_j is the reflection coeffcient. The nonlinear algebraic system for the unknown values P_j^0,$_j$ of the tubes have been obtained from the pressure-flow continuity conditions for the wave motion. The numerical method is described in (Kizilova, 2003).

3. Results and discussion

Topology of the bed influences blood distribution between the loops and the terminuses. Different variations of the diameters of the tubes and Z_t which can be considered as models of the pathologies (stenosis, spasm, bowel isemia)

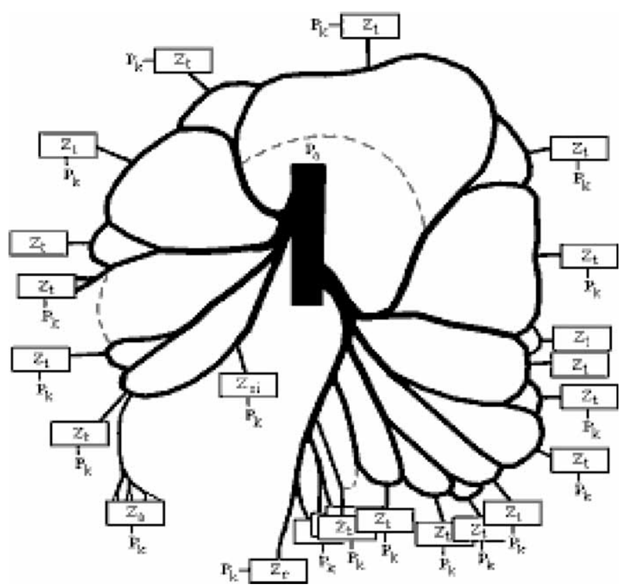

Figure 1. Model of the arterial bed of the large intestine.

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produce alterations in the blood velocities in the terminal branches. The loops ensure blood supply even at complete occlusion of one of the feeding arteries. The terminal beds near the incomplete arcs (dashed lines in figure 1) suffered from the blood insufficiency at occlusion of any tube in the system. Blood delivery to the small intestine, rectum and appendix (Z_{si}, Z_r, $Z_a$in figure 1) is defined by geometry and topology of the vasculature.

4. Conclusion

Steady and wave flow in the intraorgan beds with and without anastomoses have some differences. Topology and geometrical regularities have to be taken into account in the models of the intraorgan systems. Variations of some parameters which are proper to different pathologies can be detected by analysis of the pressure and flow waveforms in the feeding arteries.

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