卷期页码：第26卷 第3期 (2005年3月) P.316
文章编号：1000-0887(2005)03-0316-09

弹性动脉血管中血液流动特性的模拟和分析

A·克乌玛[1]，C·L·范西尼[1]，G·C·夏玛[2]

1.瑞·范西尼学院 数学和计算机科学系，阿利加赫 202001，印度；
2.基础科学研究所，坎大热，阿格拉 282002，印度

摘要：研究了两个不同的非牛顿血液流动模型：低粘性剪切简单幂律模型和低粘性剪切及粘弹性振荡流的广义Maxwell模型．同时利用这两个非牛顿模型和牛顿模型，研究了磁场中刚性和弹性直血管中血液的正弦型脉动．在生理学条件下，大动脉中血液的弹性对其流动性态似乎并不产生影响，单纯低粘性剪切模型可以逼真地模拟这种血液流动．利用高剪切幂律模型模拟弹性血管中的正弦型脉动流，发现在同一压力梯度下，与牛顿流体相比较，幂律流体的平均流率和流率变化幅度都更小．控制方程用Crank-Niclson方法求解．弹性动脉中血液受磁场作用是产生此结果的直观原因．在主动脉生物流的模拟中，与牛顿流体模型比较，发现在匹配流率曲线上，幂律模型的平均壁面剪切应力增大，峰值壁面剪切应力减小．讨论了弹性血管横切磁场时的血液流动，评估了血管形状和表面不规则等因素的影响．

关键词：弹性动脉模型；Crank-Niclson方法；非牛顿流体；壁面剪切应力
中图分类号：O242.1；O357.1；R318.01

收稿日期：2003-10-17
修订日期：
基金项目：

作者简介：

参考文献：

[1] Thurston G B.Rheological parameters for the viscosity,visco-elasticity and thixotropy of blood [J].Biorheology ,1979,16:149—155.
[2] Liepsch D, Moravec S.Pulsatile flow of non-Newtonian fluid in distensible models of human arteries [J].Biorheology ,1984,21:571—583.
[3] Rindt C C M,Van de Vosse F N,Van Steenhoven A A,et al.A numerical and experimental analysis of the human carotid bifurcation [J].J Biomechanics, 1987,20:499—509.
[4] Nazemi M,Kleinstreuer C,Archie J P.Pulsatile two-dimensional flow and plaque formation in a carotid artery bifurcation [J].J Biomechanics, 1990,23 (10):1031—1037.
[5] Rodkiewicz C M,Sinha P,Kennedy J S.On the application of a constitutive equation for whole human blood [J].J Biomechanical Engg, 1990,112:198—204.
[6] Boesiger P,Maier S E,Kecheng L,et al.Visualisation and quantification of the human blood flow by magnetic resonance imaging [J].J Biomechanics, 1992,25:55—67.
[7] Perktold K,Thurner E,Kenner T.Flow and stress characteristics in rigid walled compliant carotid artery bifurcation models [J].Medical and Biological Engg and Computing ,1994,32:19—26.
[8] Sharma G C,Kapoor J.Finite element computations of two-dimensional

arterial flow in the presence of a transverse magnetic field [J]. International J for Numerical Methods in Fluid Dynmaics, 1995, 20:1153—1161.
[9] Dutta A, Tarbell J M. Influence of non-Newtonian behavior of blood on flow in an elastic artery model [J]. ASME J Biomechanical Engg, 1996, 118:111—119.
[10] Lee R, Libby P. The unstable atheroma [J]. Arteriosclerosis Thrombosis Vascular Biology, 1997, 17:1859—1867.
[11] Korenaga R, Ando J, Kamiya A. The effect of laminar flow on the gene expression of the adhesion molecule in endothelial cells [J]. Japanese J Medical Electronics and Biological Engg, 1998, 36:266—272.
[12] Rachev A, Stergiopelos N, Meister J J. A model for geometric and mechanical adaptation of arteries to sustained hypertension [J]. J Biomechanical Engg, 1998, 120:9—17.
[13] Rees J M, Thompson D S. Shear stress in arterial stenoses: a momentum integral model [J]. J Biomechanics, 1998, 31:1051—1057.
[14] Tang D, Yang C, Huang Y, et al. Wall stress and strain analysis using a three-dimensional thick wall model with fluid-structure interactions for blood flow in carotid arteries with stenoses [J]. Computers and Structures, 1999, 72:341—377.
[15] Zendehbudi G R, Moayary M S. Comparison of physiological and simple pulsatile flows through stenosed arteries [J]. J Biomechanics, 1999, 32:959—965.
[16] Berger S A, Jou L D. Flows in stenotic vessels [J]. Annual Review of Fluid Mechanics, 2000, 32:347—384.
[17] Botnar R, Rappitch G, Scheidegger M B, et al. Hemodynamics in the carotid artery bifurcation: a comparison between numerical simulation and in vitro MRI measurements [J]. J Biomechanics, 2000, 33:137—144.
[18] Stroud J S, Berger S A, Saloner D. Influence of stenosis morphology on flow through severely stenotic vessels: implications for plaque rupture [J]. J Biomechanics, 2000, 33:443—455.
[19] 夏玛 G C, 马德胡 J, 克乌玛 A. 动脉血管流动计算的伽辽宁省金有限元法研究 [J]. 应用数学和力学, 2001, 22(9): 911—917.
[20] Milnor W R. Hemodynamics [M]. 2nd edition. Baltmore: Williams and Wilkins, 1989.
[21] White K C. Hemo-dynamics and wall shear rate measurements in the abdominal aorta of dogs [D]. Ph D Thesis. The Pennsylvania State University.
[22] Dutta A, Wang D M, Tarbell J M. Numerical analysis of flow in an elastic artery model [J]. ASME J Biomechanical Engg, 1992, 114:26—32.
[23] Patel D J, Janicki J S, Vaishnav R N, et al. Dynamic anisotropic viscoelastic properties of the aorta in living dogs [J]. Circulation Research, 1973, 32:93—98.