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Blood Flow in Human Arterial System-A Review

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Abstract

The blood flow in human arterial system can be considered as a fluid dynamics problem. Simulation of blood flow in the arterial network system will provide a better understanding of the physiology of human body. Hence, hemodynamics play an important role in the development and progression of arterial stenosis, leading to the malfunctioning of cardiovascular system. Simulation studies of blood flow in the diseased condition can diagonise the health problem easily and also have many applications in the areas such as surgical planning and design of medical devices. This paper presents a review on the existing scenario of the simulation studies of blood flow, starting with a brief overview of the structure and function of arteries and veins followed by a discussion on pressure wave propagation, blood flow models and Fluid Structure Interaction in the arterial system.

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Keywords: Arterial system, Blood flow, Newtonian fluid, Numerical study

1. Introduction

The main function of cardiovascular system is to transport nutrient and waste throughout the body. The majority of deaths reported in the developed countries result from cardiovascular diseases. Earlier, most of the cardiovascular disease affects the aged group, but, that situation is different now. There are several other risk factors for heart diseases like age, gender, use of tobacco, high blood pressure and cholesterol etc., causing the development of stenosis. Hemorheology is an area of science concerned with the blood flow and its interaction with the blood vessel through which the flow occurs. The human blood circulatory system provides essential substances such as nutrients and oxygen to the cells and transports metabolic waste products away from the same cells. Human blood is

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composed of blood cells suspended in blood plasma. Plasma, which constitutes 55% of blood fluid, is mostly water 92% by volume), and contains dissipated proteins, glucose, mineral ions, hormones and blood cells themselves. The blood cells are mainly red blood cells (also called RBCs or erythrocytes) and white blood cells, including leukocytes and platelets. The red blood cells are small semisolid particles, increase the viscosity of blood and will affect the behaviour of fluid. It has been pointed out that plasma behaves as a Newtonian fluid [1] whereas whole blood, shows non-Newtonian character [2].

Healthy blood vessels are complex in structure. There are three major types of blood vessels: the arteries, which carry the blood away from the heart at higher physiologic pressures, the capillaries, which enable the actual exchange of water and chemicals between the blood and the tissues, and the veins, which carry blood from the capillaries back toward the heart at lower physiologic pressures. Because of their different roles, their structures and wall constituents are also different. The wall of large blood vessels has a circumferentially layered structure. The most important layers are intima, media, and adventitia. The internal intima, composed of the endothelium cell. The media, which is a layered one, is responsible for most of the vessel mechanical properties. The outer layer is adventitia. Veins have a different layered configuration than arteries. They have a thinner wall, a less elastic media, and a thicker collagenous adventitia. The walls of the capillaries are extremely thin, constructed of single-layer, highly permeable endothelial cells [3].

The important feature of the arterial blood flow is its pulsatile nature. The left ventricle chamber of heart ejects the blood intermittently to the whole body system [4,5]. Normally arterial flow is considered as a laminar flow. But the development of stenosis, stiffening of arterial wall etc., will cause turbulence and reduce the required blood flow, leads to the malfunctioning of various organs. Hence detailed knowledge of blood flow is a fundamental key concept in the detection of arterial diseases [6,7]. The principal quantities which describe the blood flow are the flow velocity u and pressure p [8]. But, in the fluid-structure interaction problems, the displacement of the vessel wall due to the action of the flow field is also to be considered.

2. Simulation models

The wide span of topics such as blood pressure wave propagation, blood flow models, fluid structure interaction models etc. are covered in the literature review [10 - 40], will help the better understanding of blood flow models in humans. The related topics are discussed in the subsequent paragraphs.

2.1. pressure wave propagation

Blood pressure is the pressure exerted by the circulating blood upon the walls of blood vessels of body. Several systems of body will help the regulation of blood pressure. In arteries, blood pressure is more, compared to the vein system of the human body. Sometimes due to some abnormalities, the blood pressure in the arteries may arise. Pressure waves are formed mainly due to the pumping action of heart. Simulation studies of pressure waves in the human system has very important role in diagnosing the diseased area of the human body. For the better understanding of the blood flow in arteries, pressure wave propagation through an initially stressed tube which carries a viscous, incompressible fluid has been considered [9]. In this model, fluid is assumed as Newtonian and the tube is taken as elastic and isotropic. Even though the arterial wall in thick wall concept gives more idealistic results, but in this study the wall is assumed as thin wall. But, this study excludes the non linear terms in the fluid flow. It is found that the longitudinal displacement to large pressure increments are very large compared with the observed longitudinal oscillation of arterial wall.

By assuming the fluid flow as laminar, the pressure wave propagation through a viscous fluid flowing in a elastic thick walled orthotropic tube is studied [10]. The arterial wall motion equation is modified for longitudinal displacement with longitudinal tethering of arterial wall. In this study the reflected wave concept is also considered. It is found that the blood flow rate is decreased as pulse propagates away from the heart. Cox [11] considered the propagation of harmonic pressure waves through a homogeneous Newtonian fluid flowing through a thick walled viscoelastic tube. The motion of the fluid is described by the linearized form of the Navier-Stokes equations. The