Microvascular Research 110 (2017) 32–42

Contents lists available at ScienceDirect

Microvascular Research

journal homepage: www.elsevier.com/locate/ymvre

Simultaneous effects of coagulation and variable magnetic field on peristaltically induced motion of Jeffrey nanofluid containing gyrotactic microorganism

M.M. Bhatti [a,*], A. Zeeshan [b], R. Ellahi [b,c]

[a] Shanghai Institute of Applied Mathematics and Mechanics, Shanghai University, Shanghai200072, China
[b] Department of Mathematics and Statistics, International Islamic University, Islamabad,Pakistan
[c] Department of Mechanical Engineering, Bourns Hall, University of California Riverside, CA 92521, USA

ARTICLE INFO

Article history:
Received 2 September 2016
Received in revised form 23 October 2016
Accepted 20 November 2016
Available online 29 November 2016

Keywords:
Nanofluid
Coagulation
Blood flow
Variable magnetic field
Peristaltic flow

ABSTRACT

In this article, simultaneous effects of coagulation (blood clot) and variable magnetic field on peristaltically induced motion of non-Newtonian Jeffrey nanofluid containing gyrotactic microorganism through an annulus have been studied. The effects of an endoscope also taken into consideration in our study as a special case. The governing flow problem is simplified by taking the approximation of long wavelength and creeping flow regime. The resulting highly coupled differential equations are solved analytically with the help of perturbation method and series solution have been presented up to second order approximation. The impact of all the sundry parameters is discussed for velocity profile, temperature profile, nanoparticle concentration profile, motile microorganism density profile, pressure rise and friction forces. Moreover, numerical integration is also used to evaluate the expressions for pressure rise and friction forces for outer tube and inner tube. It is found that velocity of a fluid diminishes near the walls due to the increment in the height of clot. However, the influence of magnetic field depicts opposite behavior near the walls.

1. Introduction

In a living body, peristaltic flow occurs due to simultaneous contraction and expansion of smooth muscles that transfer across the whole length of a tube or channel. It can easily be observed in different parts of the human body i.e. propagation of cilia, propagation of blood in arteries, movement of the ovum in fallopian tubes, urine transport of kidney to bladders and many others. In biomedical engineering different devices such as heart-lung machine and dialysis works on the phenomena of peristalsis. However, it also involves in multiple industrial applications such as corrosive fluids, propagation of sanitary fluids, and drug delivery systems. Different researchers analyzed the peristaltic flow with various biological fluid models in disparate conditions and media (Akbar, 2015; Akbar et al., 2016a; Akbar et al.; Bhatti et al., 2016b; Goswami et al., 2016). Most of the authors presented the peristaltic flow mechanism with viscous (Newtonian) fluids. However, this is not enough in such a way that microfluidic device are applied to examine the biofluids. These are the only solutions of long-chain molecules reveals a non-Newtonian attitude which is scrutinized by memory effects, yield stress, variable viscosity, the hysteresis of fluid features and normal stress influence. Moreover, the non-Newtonian fluid includes in different procedures such as movement of chyme, blood flow (hemodynamics), propagation of liquid metals, alloys and slurries. Tripathi et al. (2010) examined the peristaltic motion of non-Newtonian Maxwell fluid model through a channel and presented the series solution using Homotopy perturbation method (HPM). Tripathi and Beg (2015) investigated the sinusoidal motion (peristaltic motion) of Maxwell fluid under the effects of slip boundary conditions using Homotopy analysis method. Recently, Tripathi et al. (2015) simulated the peristaltic flow of viscoelastic biofluid through a porous asymmetric channel using Differential transform technique. Abbas et al. (2016) studied the peristaltic flow in a three-dimensional rectangular compliant channel. He obtained the series solution using Homotopy perturbation method. More recently, Ellahi et al. (2016) explored the peristaltic motion of couple stress fluid in a non-uniform rectangular duct. He considered the walls of the rectangular duct as compliant and presented the exact solutions.

During the past few years, nanofluid dynamics have grabbed the concentration of different researchers due to its wide range of applications in biology, engineering, and medical science etc. Initially,

* Corresponding author.
E-mail addresses: muhammad09@shu.edu.cn, mubashirme@yahoo.com (M. Bhatti).

http://dx.doi.org/10.1016/j.mvr.2016.11.007
0026-2862/

Choi (1995) presented the term nanofluid and described a new approach to improve the energy performance. Although, the basic concept of nanofluid was firstly described in 19th century by "James Clark Maxwell". Later, Lee et al. (1999) illustrated that the nanofluids are the advanced class of fluids that are devised by an inclusion of nanoparticles in base fluids such as ethylene glycol, oils, propyleneglycol, water, silk fibroin, lubricants, and biofluids. Nanoparticles are composed of metals, carbides, oxides and nonmetals such as aluminum, copper, graphite, carbon nanotubes, titanium, iron and many others. Furthermore, the other benefits of nanofluid include enhancement of heat transfer rate, minimum clogging, cooling of a microchannel, nano-drug delivery, and many others. In the current era, different scientist, engineers, physiologist, and mathematicians are engaged to analyze nanofluid mechanism associated with a peristaltic flow. Initially, Akbar et al. (2012) describe the peristaltic motion of viscous nanofluid through a uniform diverging tube and obtained the series solution for velocity profile, concentration profile and temperature profile using Homotopy perturbation method. Later, Akbar and Nadeem (2012b) considered the non-Newtonian Phan-Thien-Tanner fluid model to analyze the peristaltic nanofluid motion through a diverging tube. Akbar (2014b) explored the peristaltic flow of Jeffrey nanofluid towards a diverging tube and obtained the eat solution for velocity distribution whereas, perturbation solution are presented for temperature and concentration profile. Tripathi and Bég (2014) introduced the application of drug delivering using a peristaltic flow of viscous nanofluid through a uniform channel. Ghasemi et al. (2016) studied analytically and numerically the impact of nanoparticle on peristaltic flow through a drug delivery systems. Akbar et al. (2016c) investigated the peristaltic flow of nanofluid using copper oxide nanoparticles through a permeable tube in the presence of heat transfer. Kothandapani and Prakash (2016) examined the impact of slip and convective boundary conditions on peristaltic flow of Jeffrey nanofluid through a tapered asymmetric channel and obtained the series using Homotopy perturbation method. Akbar (2014a) analyzed the effects of double-diffusive natural convection on peristaltic Jeffrey nanofluid flow through a porous channel. Recently, Bhatti and Zeeshan (2016) analytically analyzed the peristaltic flow of two-phase flow of Jeffrey fluid model with variable viscosity through a uniform channel.

Coagulation (blood clotting) is a major and important mechanism that helps to stop bleeding during the injury of a blood vessel. Clot arises in arteries and veins. Platelets (blood cell) and proteins simultaneous corresponds to prevent the injury by a formulation of a clot at the injury point. Arteries and veins are helpful to propagate the blood through the vessels, although both the vessels perform differently. Most of the theoretical and experimental investigations presented in which blood and other biological fluids are treated as Newtonian. Although this approach is useful in order to analyze the peristaltic flow in a ureter, but through this approach, it is unable to provide satisfactory results in lymphatics vessels and tiny blood vessels. According to some recent studies (Nagarani and Lewis, 2012; Rani and Sarojamma, 2004; Sreenadh et. al, 2011), it is found that different biological fluid models reveal non-Newtonian behavior. In tiny blood vessels, blood depicts shear dependent viscosity and needs a finite yield stress before the flow can begin, therefore, to consider the blood as non-Newtonian is an important and major factor in a modeling. Abzal et al. (2016) investigated simultaneously, the effects of radiation, joule heating and slip on peristaltic blood flow towards a coaxial asymmetric tapered porous channel. Mekheimer et al. (2016a) presented a micropolar blood flow induced due to peristaltic wave in the presence of nanoparticles and magnetic field. Akbar et al. (2016b) discussed the rheological properties of blood flow of Reiner–Rivlin fluid model through a tapered artery in the presence of stenosis. Mekheimer et al. (2016b) considered the blood flow through a stenotic artery in presence of metallic nanoparticles. Srinivasacharya and Rao (2016) presented the mathematical model of couple stress fluid of blood flow towards a bifurcated artery. Mekheimer and Mohamed (2014) investigated the peristaltic motion of pulsatile flow of two-phase flow through an annulus and presented the application for clot blood model.

Nowadays, an endoscope is a substantial tool to determine different physical problems in a human body in which fluid moves using the mechanism of peristalsis. There are various kinds of an endoscope which usually rely upon the site of a body and the kind of process. In most of the cases, the term endoscope often uses to analyze the upper part of a gastrointestinal tract, called as "esophagogastroduodenoscopy". The endoscope is also helpful in determining various kinds of diseases such as cancers of a digestive system, bleeding, difficulty in swallowing food, gastrointestinal bleeding, and many others. El Naby and El Misiery (2002) analyzed the effects of the endoscope on Newtonian fluid model induced due to peristaltic wave. Mekheimer (2008) explored the effects of an endoscope on peristaltic flow of couple stress fluids. Later, he (Mekheimer and Abd Elmaboud, 2008) examined the same problem but considered the porous media. Tripathi (2011) presented an application of endoscope on peristaltic motion of non-Newtonian Maxwell fluid through a uniform tube. Akbar and Nadeem (2011) examined the peristaltic nanofluid flow in the presence of endoscope. Akbar and Nadeem (2012a) investigated the endoscope with heat and mass transfer on peristaltic flow of Ree–Eyring fluid through a channel. He obtained the analytical and numerical solution using perturbation and shooting method. Bhatti et al. (2016e) simultaneously investigated the endoscope and slip effects on peristaltic blood flow through an annulus. Recently, El-dabe et al. (2016) studied the electrohydrodynamic peristaltic flow with endoscope effect and mild stenosis using Oldroyd fluid model.

The study of magnetic nanoparticles has numerous applications in biomedical engineering and physics. Magneto nanoparticles are a gang of nanoparticles that are maneuver in the presence of a magnetic field. Magnetic nanoparticles have analyzed by numerous researchers due to its multiple applications such magnetic resonance imaging, magnetic drug targeting, biomedicine, magnetic nanoparticles to heal the cancer disease and immunotherapy. In the field of nanomedicine, magnetic nanoparticles are directly transmitted into a human body using intravenous injection method. Nowadays, it is found that magnetic nanoparticles provide an effective solution in clot-dissolving enzymes. Blood clots are major cause of strokes and heart attacks that lead to death worldwide. The main objective of such kind of medicine is to resolve the blood clot problem and continue the flow of blood in vessels. Due to such kind of applications, various authors analyzed the peristaltic nanofluid flow in the presence of magnetic field. Abd-Alla et al. (2015b) studied the peristaltic flow of non-Newtonian fluid (Jeffrey) in the presence of varying magnetic field through a tube with endoscope effect. Srinivasacharya and Rao (2015) investigated the magnetohydrodynamic influence on couple stress fluid towards a bifurcated artery. Abd-Alla et al. (2015a) examined the rotation effect on a radially varying magnetic field with endoscope effect on peristaltic flow through a tube. Akram (2016) explored the peristaltic flow of fourth-grade nanofluid flow under the effects of an inclined magnetic field. Some novel studies on the current topic are available in Refs. Abbas et al. (2016), Bhatti et al. (2016a,c,d), Ezzat et al. (2000), Othman et al. (2016), Othman and Ezzat (2001), and Rashidi et al. (2016).

Inspired by the above applications and discussion, the objective of present study is to investigate the coagulation (blood clot) and variable magnetic field on peristaltic induced motion of Jeffrey nanofluid in the presence of the gyrotactic microorganism. Long wavelength approximation and small Reynold's number assumption are applied to model the governing equations. Series solutions are presented for velocity profile, motile microorganism density profile, nanoparticle concentration profile and temperature profile. The behavior of all the sundry parameters is discussed and displayed using graphs.