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Analysis of Blood Flow Parameters to Detect Abnormalities in Blood Vessels

Monica D'Souza*, Purti Savardekar **
Dept. of Electronics and Telecommunication Engineering
Goa College of Engineering
Ponda-Goa, India

***Abstract*— The cardio vascular network of our human body consists of a large number of blood segments and thus, the blood flow inside our human body is very complicated. Not only the blood pressure but also, the blood flow is important. It describes the flow of blood to different parts of the body. One of the most interesting phenomena is the transition to turbulence. Blood flows that are usually smooth and in order, may become complex. This complex nature is very difficult to analyze. This process is known as transition to turbulence.**

Recently various techniques have been developed for blood flow analysis. These techniques help in analyzing and detecting abnormalities in blood flow. This paper focuses on a numerical approach to examine blood flow. Navier Stokes equations rule the fluid motion. These equations were implemented in MATLAB to analyze the behavior of blood flow. This proposed paper provides a literature survey and a numerical approach to automatically detect any abnormalities in blood vessels.

Keywords— Blood Flow, Aneurysms, Hemodynamic Characteristics

1. INTRODUCTION

Due to cardiovascular diseases, the mortality rate in developed countries is very high. The major parts of our body such as: the brain- suffers from stroke and the heart-suffers from myocardial infraction etc. These conditions are fatal and may cause instant death. For this reason, the study of blood flow is important.

The blood flow in a human body is supposed to be mostly laminar which has a constant velocity. Due to its constant velocity, the flow of blood is easy to analyze. Also, the flow pattern will be smooth i.e. it is not disrupted. Turbulent blood flow occurs when there is an abnormality in blood vessel, which means that the blood flow is very complex. These abnormalities could be a clot or an aneurysm which disrupts the flow of blood, which does not allow the blood to reach its required destination. Therefore, an early detection and monitoring of abnormalities is of utmost importance. In recent times a number of techniques have been proposed to analyze blood flow.

This paper provides a literature survey and a numerical approach implemented in MATLAB to detect abnormalities in blood vessels. Early detection of abnormalities will prevent fatal events such as instant deaths.

2. LITERATURE SURVEY

If the walls of arteries weaken, the velocity and pressure of the blood flow changes. A weakened artery if not diagnosed and treated on time may give rise to aneurysm and in time might rupture, thus causing even bigger problem such as stroke and myocardial infraction etc. Numerous computer simulation schemes have been developed over the years to diagnose weakened blood vessels, aneurysms and other abnormalities in blood vessels. This section of the paper mainly focuses on the different approaches developed over the years by the authors in literature for accurate ways to detect abnormalities on blood vessels.

Steffen Oeltze-Jafra, Juan R. Cebral, G´abor Janiga, and Bernhard Preim in [1] proposed that Computer Fluid Dynamics (CFD) simulations help in understanding the dynamic characteristics of the flow of blood to extract crucial and important information for proper diagnoses. The studies say that there are vortices (or even embedded vortices) present in the blood flow patterns. These vortices lead to aneurysm rupture. In this approach, a clustering approach is presented for analysis of vortical blood flow. streamlines of the blood flow are analysed and grouped together to find embedded vortices. These grouped streamlines show a detailed visualization of the blood flow pattern. These visualizations were also viewed by a group of experts to view the simulation results. It was concluded that hemodynamic characteristics are important to detect abnormalities in blood vessels. The more dynamic characteristics analysed the better is the detection process.

Rocco Gasteiger, Dirk J. Lehmann, Roy van Pelt, G´abor Janiga, Oliver Beuing, Anna Vilanova, Holger Theisel, and Bernhard Preim in [2], also use different types of hemodynamic characteristics such as, inflow jet and impingement zone that are also related to the risk of aneurysm rupture. These parameters are investigated visually by CDF. Here, streamline properties of the blood flow are used to find out the inflow jet and impingement zone. A boundary contour was used to extract the inflow jet on the ostium (neck of an aneurysm) which was then used to identify the impingement zone. This is an automatic and robust method to detect abnormalities in blood vessels.

H. Zakaria, A. Kurniawan, T.L.R. Mengko, and O.S. Santoso in [3] described an approach to detect celebral aneurysm by using one of the most advance techniques of 2D digital subtraction angiogram (DSA) imaging. Here, time to peak and time duration of flow of contrast agent that travels in the blood vessels have been calculated. DSA imaging is an advanced and improved method over traditional techniques to visualise blood vessels and subtract the other structures of the human body. The time duration for the contrast agent to travel in a blood vessel will be different for a normal blood vessel and an abnormal blood vessel, therefore an abnormality can be detected. This is a simple, yet effective method of detecting an abnormality. Large aneurysms (greater than 7mm) can be detected using this method.

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3. HEMODYNAMIC PARAMETERS

The dynamics of blood flow is called as Hemodynamic parameters. They play an important role in detecting abnormalities in blood segments. Hemodynamic tells us the physical law that governs the blood flow [4]. When the flow particles in the blood segments are parallel and moving in one direction, it is considered as laminar flow. When the flow is irregular it is considered as turbulent flow. The transition of blood flow from normal to turbulent is due to abnormal blood segments. Therefore, hemodynamic parameters are diagnosed to find out the fault in blood vessels so that, the necessary treatment can be done.

3.1. Vortices

Vortices is a major part of turbulent flow. When blood flows in a circular direction in a blood vessel, vortices are formed. These vortices then give rise to blood clots. Therefore, detection of vortices is an important hemodynamic parameter.

3.2. Inflow Jet

This parameter is currently visually examined obtained by CFD. This parameter tells us the streamline of the blood flow. With the help of CFD the streamline properties of the blood flow are examined. Any irregularities in the streamlines will show an abnormality in blood segments.

3.3. Impingement Zone

This hemodynamic parameter is clubbed along with Inflow Jet to find the affected area of the blood vessel.

4. NAVIER STOKES EQUATIONS

The Navier-Stokes equations governs the motion of fluids and can be seen as Newton's second law of motion for fluids. These equations cab be seen as the heart of fluid flow. Solving them, predicts the fluid velocity and its pressure in a given geometry. In other words, these equations can be used to find out the velocity and pressure changes in a blood vessel. It is relatively easy to solve these equations for a flow between two parallel plates or a circular pipe.

5. IMPLEMENTATION AND RESULTS

An analytical approach, that is, Navier stokes equations have been used to detect abnormalities in blood vessels. This method was implemented in MATLAB, by using the pde tool which is an arrangement of Stokes equations. Figure 1 shows the simulation results for a normal blood flow. The color codes show the different velocity profiles. The velocity is evenly distributed with the highest velocity in the center on a blood segment. Figure 2 show the velocity profile for an abnormal blood flow.

Navier Stokes equations were simple and effective to study abnormal blood vessels.

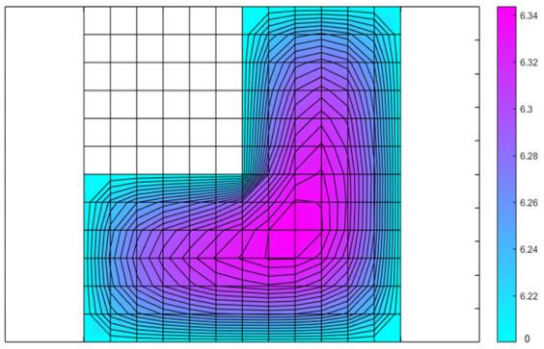

Figure 1

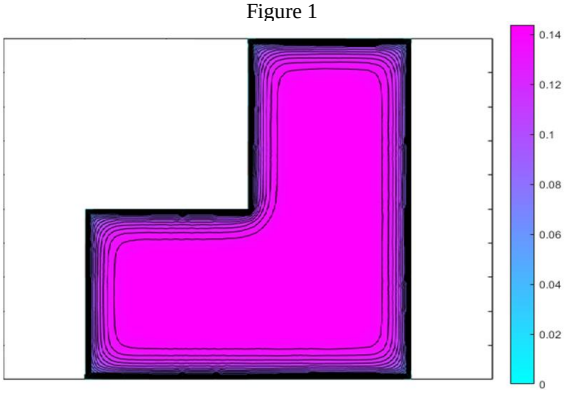

Figure 2

6. CONCLUSION

Not only the blood pressure, but also, the blood flow gives important information. It describes the supply of blood that reaches the organs and tissues. Abnormal changes in the blood flow changes the velocity and pressure of the blood flow. These abnormalities could be due to various reasons because of which it needs to be diagnosed on time to receive proper treatment and fatal events can be avoided.

This proposed paper provides a survey of various techniques and algorithms proposed in literature. A method to automatically detect abnormalities in blood vessels has been implemented in MATLAB. The simulations show normal and abnormal blood vessels with different velocity profiles. If an abnormal blood segment is not detected it could be fatal and could lead to an aneurysm. Therefore, the algorithm developed for blood flow analysis must provide high degree of accuracy and fast execution time.

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