# NUMERICAL STUDY OF THE BLOOD FLOW IN AORTIC ANEURYSM

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# NUMERICAL STUDY OF THE BLOOD FLOW IN AORTIC ANEURYSM

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**This report is submitted**
**in fulfillment of the requirement for the degree of**
**Bachelor of Mechanical Engineering**

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**Faculty of Mechanical Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**JUNE 2021**

**DECLARATION**

I declare that this project report entitled “Numerical Study of The Blood Flow in Aortic Aneurysm” is the result of my own work except as cited in the references

Signature : 

Name : AIDA NAZURAH BINTI SELAMAT

Date : 19 JUNE 2021

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**APPROVAL**

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

Signature :.....

Name of Supervisor: DR. MOHAMAD SHUKRI BIN ZAKARIA

Date :.....

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## DEDICATION

This study is wholeheartedly dedicated to my beloved parents and my family members. They have been my constant source of inspiration and strength and continually provide their emotional and financial support when writing this report on the Pandemic Era of Covid-19.

The study is also fully dedicated to the respectful people who have to lend a hand for their assistants and advice to complete the study on the Numerical Study of The Blood Flow in Aortic Aneurysm.

Last but not least, I would like to express my dedication to and for readers and researchers who will be using this report for future references.

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## ABSTRACT

An aneurysm is caused by the lower strength of the blood vessel. Therefore, an aneurysm commonly occurs in arteries rather than veins due to the vein's lower blood pressure. This study is cognate of the diagnosed aneurysm aorta's geometry design and the effect on the hemodynamic of the aorta, leading to heart failure. The study aims to develop CFD models of blood flow in the ascending aorta vessel and simulate and validate blood flow through the healthy aorta with previous available literature. This study also focused on analysing hemodynamic flow characteristics such as velocity, pressure drop, and wall shear as a predictive tool for possible Thoracic Arterial Aneurysms diseases. The model is used by the extraction of the healthy aorta's geometry from gated clinical cardiac 64-slice CT scans obtained by the National Heart Institute (IJN), Malaysia and the model of the bulge of aorta with aneurysms condtion is developed by referring to previous study with the maximum diameter of 52.40 mm. The simulation of the aorta is comducted by using ANSYS Fluent with k- epsilon, realizable and enhance wall treatment model. The result shows that the average velocity, pressure, and turbulent kinetic energy of the healthy aorta streamline are $6.184\times10^{-2}$ m/s, 5.884 Pa, and $1.028\times10^{-4}$ $m^2/s^2$. The simulation result of the hemodynamic of diagnosed aorta such as the average velocity, pressure and turbulent kinetic energy are $5.485\times10^{-2}$ m/s, 5.485 Pa and $2.091\times10^{-4}$ $m^2/s^2$. The result indicates that the changes in the diameter of the aorta wall by a bulge can affect the hemodynamic flow of the aorta. The velocity drops each condition has a similar value. However, the static pressure value, wall shear stress undergoes the value decrement while the turbulent kinetic energy undergoes an increment. The increment of the aorta diameter leads to the lower velocity value of the blood flow. While the aorta undergoes the condition, the pressure drop will increase, causing the risk of the aorta rupture to increase.

## *ABSTRAK*

*Gejala aneurisma berlaku disebabkan kurangnya ketahanan dinding di salur darah. Oleh yang demikian, penyakit aneurisma juga sering berlaku di kawasan arteri secara majoritinya daripada berlaku di kawasan vena, oleh kerana saluran vena yang mempunyai tekanan darah yang rendah. Hasil kajian ini adalah sebuah analisis menyeluruh tentang model rekabentuk aorta anuerisma serta analisa hemodinamik di saluran aorta tersebut yang boleh menyebabkan risiko penyakit jantung. Tujuan hasil kajian ini adalah untuk membina model kepada penyaliran darah di kawasan utama aorta dengan berbantukan kajian yang lepas. Kajian ini juga ditekankan analisis hemodinamik seperti halaju, penurunan tekanan serta tekanan ricih dinding sebagai analisis ramalan untuk aneurisma aorta torakalis pada masa akan datang. Model yang digunakan dalah daripada pengekstrakan data daripada kardiak klinikal 64-kepingan pengimbasan CT yang didapati oleh Institut Jantung Negara (IJN), Malaysia serta daripada kajian yang lepas untuk pembuatan model aorta aneurisma dengan diameter, 52.40 mm. Simulasi ini dilakukan dengan menggunakan perisisan ANSYS Fluent dengan model k-epsilon, relizabel dan model dinding dipertingkatkan. Kajian dapati bahawa purata halaju, tekanan dan tenaga kinetic turbulen dari saliran aorta yang sihat adalah $6.184\times10^{-2}$ m/s, 5.884 Pa, dan $1.028\times10^{-4}$ $m^2/s^2$. Hasil kajian untuk aorta yang dijangkiti aneurisma untuk purata halaju, tekanan dan tenaga kinetic turbulen dari saliran aorta ialah $5.485\times10^{-2}$ m/s, 5.485 Pa, $2.091\times10^{-4}$ $m^2/s^2$. Daripada hasil kajian ini, kajian ini didapati bahawa perubahan daripada diameter dinding aorta yang lebih besar daripada simptom aneurisma boleh menyebabkan perubahan yang signifikan terhadap analisa hemodinamik aorta tersebut. Perubahan antara halaju terhadapa kedua-dua aorta mempunyai nilai yang hampir sama. Akan tetapi, tekanan statik, tekanan ricih dinding mengalami nilai penurunan and tenaga kinetik turbulen mengalami nilai kenaikan. Pengingkatan Panjang diameter boleh menyebabkan perunan halaju saliran darah. Sepertimana keadaan aorta berlakunya aneurisma, penurunan tekanan juga boleh naik dan boleh menyebabkan risiko pemecahan dinding aorta.*


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## CONTENT



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## LIST OF ABBREVIATIONS

| | |
|---|---|
| Computational Fluid Dynamics | CFD |
| Thoracic Aortic Aneurysm | TAA |
| Thoracic Aortic Disease | TAD |
| Wall Shear Stress | WSS |
| Aortic Stenosis | AS |
| Computed Tomography | CT |

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## LIST OF SYMBOLS

| | |
|---|---|
| Density | $\rho$ |
| Viscosity | $\mu$ |
| Change in The Value of Certain Variable | $\Delta$ |
| Velocity | $u, v, w$ |

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# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND

The cardiovascular system equates to the body fluid transport system. This system has three key components: the heart, the vessel, and the blood itself. The heart is the organ pump, and the blood vessels are like the routes of transmissions. Blood is the fluid containing the oxygen and nutrients needed by the body and retaining the removable waste. The characteristic of blood flow in the blood vessel is also known as Hemodynamics. Hemodynamics inaugurate with the heart, which transports the driving force for all blood flow in the body. There is specific pressure, velocity for the blood flow to be considered a normal condition on the blood vessel for a healthy human body. The average peak and mean blood velocities were 66 11 cm/sec and 11 cm/sec in the ascending Aorta (Ivor T. G.,1969). However, several common cases regarding the cardiovascular system cause some abnormal behaviour of the velocities and the blood pressure, focusing for the most part on the aorta. One of the cases is aortic aneurysms. Figure 1.1 shows the difference between the healthy aorta and diagnosed aorta.

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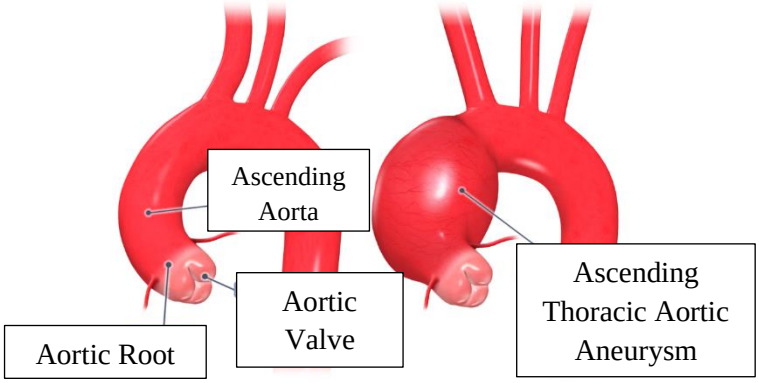


(a) (b)

Figure 1.1 (a): Condition on healthy Aorta (S. T. S., 2018). (b) Aorta condition on thoracic aortic aneurysms (S. T. S., 2018.)

Based on Greek, the word aneurysm is established from the word *aneurysma*, which means dilation. In general, an aneurysm is an abnormal bulge in the vessel. However, in scientific term, an aneurysm is commonly due to aortic dissection or arteriosclerosis (Virginia P., BA, 1980). An aneurysm is caused by the lower strength of the blood vessel. Therefore, an aneurysm commonly occurs in arteries rather than veins due to the vein's lower blood pressure. 40% of aneurysms were identified in the ascending aorta on the 260 patient's data (Virginia P., 1985). In this manner, before the disease becomes symptomatic and presents severe problems and increased surgical mortality, thoracic aortic aneurysms should be recognized and resected early.

## 1.2 PROBLEM STATEMENT

There are several research and papers showing hundreds of cases of thoracic aneurysms in patients. For example, based on Virginia Pressler (1980), the survival rate was 50% for patients who underwent elective resection, 30% for patients treated in surgery, and 21% for not treated surgical patients. However, in some cases, the medical surgeon cannot perform an accurate surgery due to their knowledge of the exact Hemodynamics of the Aorta, such as precise wall shear stress estimation when the aorta in the body was diagnosed in the thoracic aneurysm. Based on J. Febina et al. (2018), high turbulence intensity values were commonly observed near the aneurysm outlet. Therefore, the wall shear stress values of the aorta obtained could be overestimated. According to Ralf Kolvenbach (2009), the thoracic aortic aneurysm cases on the diagnosed aorta vessel were resected by using an open approach with preimplantation of the intercostal arteries. Therefore, for the surgeon to perform the specific surgery on the aorta to remove the bulge in it, they need to analyses the Hemodynamics of the diagnosed Aorta.

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The analysis process needs to be simulated by Computational Fluid Dynamics (CFD) in which are the most accurate or within the less error of the actual condition of the aorta, which makes the result become more accurate and will determine the specific surgery on the patient. Therefore, a better geometry simulation design of both aorta conditions using the Computational Fluid Dynamic (CFD) analysis of the hemodynamic can help prevent the surgery's mortality in the aorta, leading to the survival chance of the patient.

## 1.3 OBJECTIVE

This study is cognate of the diagnosed aneurysm aorta's geometry design and the effect on the hemodynamic of the aorta, leading to heart failure. The main thrusts of this study to achieve a better result, which is as follows;

1. To develop CFD models of blood flow in the ascending aorta vessel.
2. To simulate and validate blood flow through a healthy Aorta with previous available literature.
3. To analyse the hemodynamic flow characteristics such as velocity, pressure drop, and wall shear as a predictive tool for possible Thoracic Arterial Aneurysms diseases.

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## 1.4 SCOPE OF STUDY

This study highlights the numerical study of the blood flow in the human heart based on aortic aneurysm disease in the patients. However, this study focuses only on thoracic arterial aneurysms diseases in the thoracic area of the body. Therefore, the design and the analysis are only taking part in the aorta blood vessel because the aorta is the most vital blood vessel that feeds oxygenated blood to the body. Therefore, those problems may cause serious health problems more than abdominal aortic aneurysms based on past research. Therefore, the hemodynamic analysis, such as the shear stress of the aorta's wall, the blood flow velocity, and pressure, will be focused on the healthy aorta simulation and diagnosed aorta simulation in CFD.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Cardiovascular System

### 2.1.1 Introduction

The human body consists of several systems such as the Digestive system, Immune system, Endocrine system, and Cardiovascular System. Cardiovascular is one of the vital systems in the body because generally, the system functioned as blood transportation, whether it is oxygenated on deoxygenated throughout the body.

The cardiovascular system majorly in three keys which is the heart as the pump throughout the body. The blood acts as the working fluid to transport oxygen and nutrients in order for the body to survive, and the arterial system which consists of the cardiac cycle. According to Kroeker, C. G. (2018), blood flow has its magnitude and behaviour, which depends on the mechanical properties of the heart muscle and the strength of the blood vessel wall. The blood fluid properties are also taken as a significant value for the cardiac cycle to have functioned. According to Wayne W. LaMorte (2016), the schematic of the blood circular system on the body is shown in Figure 2.1.

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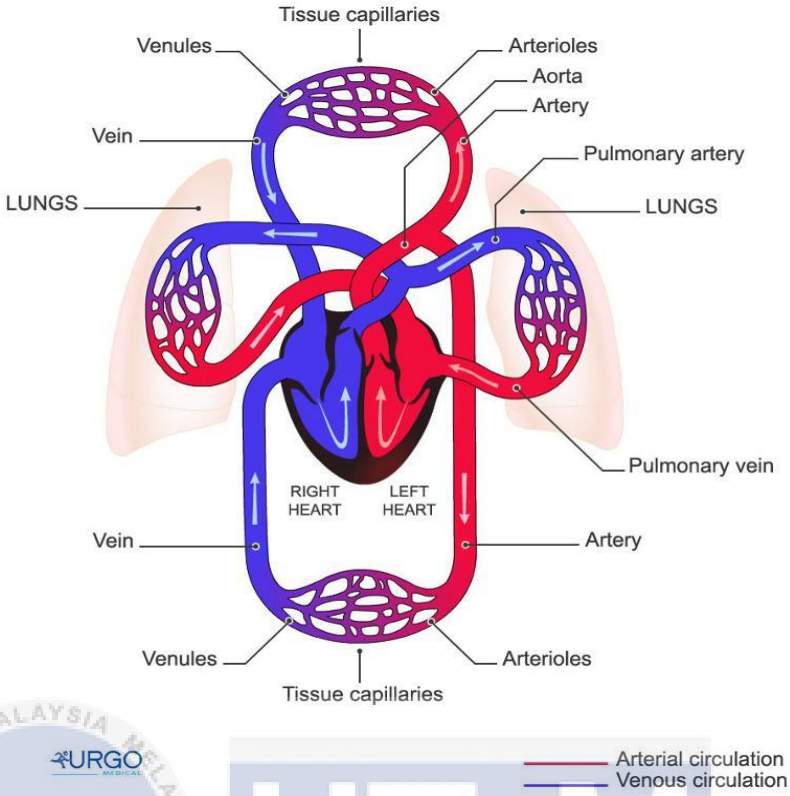


Figure 2.1: The blood circulatory system of the body

The arterial system is the system where oxygenated blood is transported in the blood vessel by using the heart, which acts as the pump of the body. The blood travels from arteries to arterioles to blood capillaries. The deoxygenated blood and byproducts are returned from the capillaries by using venules through the vein. According to Wayne W. LaMorte (2016), there are two parts of the blood circulatory system, which is the right side of the heart, scientifically right atrium, and right ventricle, and function as deoxygenated blood receiver from the periphery and transport it to the lungs via the pulmonary artery for re-oxygenation. Once blood is re-oxygenated from the lung, it returned to the left side of the heart via the pulmonary veins. After entering the left atrium, blood enters the left ventricle and is pumped into the aortic arch for distribution to the whole body.

The cardiovascular system has its complications and disease. More often than not, an unhealthy cardiovascular system might be diagnosed due to the unhealthy habit of the owner of the body, such as smoking and drinking alcohol. On the contrary, some of the cases involved the malfunction of the cardiac cycle based on genetic disease. Based on Glazier and Anne M. (2002), while several single genes are the cause of

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monogenic cardiovascular disorders, fewer genes have been reported that embody complex joint, cardiovascular diseases. For example, 20% of patients with thoracic aortic aneurysms (TAA) root a dominant pattern of inheritance of the family hereditary, which resulting thoracic aortic disease (TAD) from a mutation in the single gene (Pinard et al., 2019). Therefore, in these such diseases, it may lead to cardiac cycle failure, and it needs to be identified what the causes and the characteristic of the hemodynamic flow of the cardiovascular system are.

### 2.1.2 The Anatomic of the Heart

The heart beats around 100,000 times a day, pumping approximately 8 pints of blood throughout the body every day. The heart delivers oxygen- and nutrient-rich blood to tissues and organs and carries away waste, and is located slightly left of centre in the chest. A wall of tissue called the septum separates the left and right atria and the left and right ventricle (Payal Kohli and Tim Newman, 2020). In the body, the heart weighs between 280 to 340 grams in men and 230 to 280 grams in women (Henry Gray, 1918). The function of the heart is based on the blood flow of the heart. There are four main parts of the heart as shown as in Figure 2.2.

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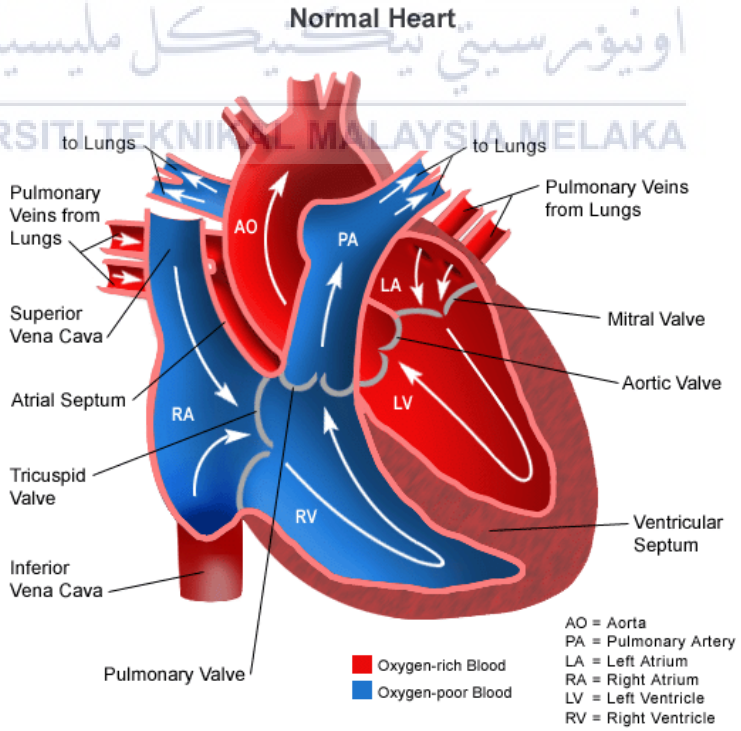


Figure 2.2: The anatomy of the heart and the vector of the blood flow (Da Silva Fabio, 2017).