FINITE ELEMENT MODELING OF ABDOMINAL AORTIC ANEURYSM

MOHD IZZAT BIN SAMSUDIN

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

MEI 2010

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

Signature:
Name of Supervisor: Mohd Akramin Bin Mohd Romlay
Position: Lecturer
Date: 6 MEI 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature:

Name: Mohd Izzat Bin Samsudin

ID Number: MA06022

Date: 6 MEI 2010

ABSTRACT

An aneurysm is an abnormal bulging or widening of a portion of an artery due to weakness in the wall of the aortic wall. This is happening when the mechanical stress exceeds the tensile strength of the tissue. Aneurysm can happens anywhere in parts of our body as long there is an aorta. Nowadays, an accurate decision to predict the rupture of the aneurysm is not is founded yet and usually, clinical doctors will treat the aneurysm base on the aneurysm size. This study is focusing on abdominal aortic aneurysm that is occurring at the area of abdomen aorta. By using the simulation tools, the stress behavior on this region will be analyzed. The normal size of abdomen aorta is about 2 cm and aneurysm can make this aorta to reach to 6 cm. As the size of an aneurysm increases, there is a potential of rupture of aneurysm. This can result in severe hemorrhage or even worst, fatal event. The studies being proceed without experiment but only based on numerical approach. From the previous studies, it was shown that the mechanical behaviors inside aneurysm region would be different compare to the normal blood vessel. It was proves that a large stress distribution appear at both necks and around the aneurysm bulge on the anterior surfaces. Studying the mechanical properties in real AAAs would be useful information to the clinical doctors because it helps them to better understand of aneurysm behavior.

ABSTRAK

Aneurism adalah kejadian ganjil pembengkakan atau pembesaran bahagian arteri disebabkan oleh dinding aorta yang lemah. Kejadian ini berlaku apabila tekanan mekanikal melebihi kekuatan tegangan dinding aorta. Aneurism boleh terjadi di mana-mana bahagian badan kita yang mempunyai salur darah. Pada hari ini, keputusan yang tepat untuk meramal aneurism akan pecah belum masih ditemui dan kebiasaannya, doktor akan merawat aneurism berdasarkan saiz aneurism. Kajian ini akan difokuskan di abdomen aneurism yang berlaku di kawasan salur darah di perut. Dengan mengunakan kaedah simulasi, sifat-sifat tekanan di kawasan ini akan dianalisis. Saiz normal untuk salur darah di bahagian perut adalah 2 cm dan aneurism boleh menyebabkan salur darah ini mencecah 6 cm. Apabila saiz aneurism meningkat, terdapat potensi untuk aneurism pecah. Ini boleh menyebabkan pendarahan atau lebih teruk, kematian. Kajian ini hanya dijalankan dengan pendekatan berdasarkan pengiraan matematik tanpa melibatkan sebarang eksperimen. Berdasarkan kajian lepas, telah ditunjukkan bahawa sifat-sifat mekanikal di dalam bahagian aneurism adalah berbeza dengan salur darah yang normal. Telah dibuktikan bahawa taburan tekanan yang kuat berlaku di kedua-dua pangkal dan sekitar bahagian pembengkakan aneurism. Dengan mengkaji sifat-sifat mekanikal di abdomen aneurism yang sebenar dapat memberikan maklumat-maklumat yang berguna kepada doktor-doktor kerana ini dapat menolong mereka untuk lebih memahami keadaan aneurism.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF ABBREVIATIONS

MSD	Musculoskeletal disorders
SME	Small and medium enteprise
MARDI	Malaysian Agricultural Research and Development Institute

ABSTRACT

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ABSTRAK

Aneurism adalah kejadian ganjil pembengkakan atau pembesaran bahagian arteri disebabkan oleh dinding aorta yang lemah. Kejadian ini berlaku apabila tekanan mekanikal melebihi kekuatan tegangan dinding aorta. Aneurism boleh terjadi di mana-mana bahagian badan kita yang mempunyai salur darah. Pada hari ini, keputusan yang tepat untuk meramal aneurism akan pecah belum masih ditemui dan kebiasaannya, doktor akan merawat aneurism berdasarkan saiz aneurism. Kajian ini akan difokuskan di abdomen aneurism yang berlaku di kawasan salur darah di perut. Dengan mengunakan kaedah simulasi, sifat-sifat tekanan di kawasan ini akan dianalisis. Saiz normal untuk salur darah di bahagian perut adalah 2 cm dan aneurism boleh menyebabkan salur darah ini mencecah 6 cm. Apabila saiz aneurism meningkat, terdapat potensi untuk aneurism pecah. Ini boleh menyebabkan pendarahan atau lebih teruk, kematian. Kajian ini hanya dijalankan dengan pendekatan berdasarkan pengiraan matematik tanpa melibatkan sebarang eksperimen. Berdasarkan kajian lepas, telah ditunjukkan bahawa sifat-sifat mekanikal di dalam bahagian aneurism adalah berbeza dengan salur darah yang normal. Tekanan effektif menunjukkan perbezaan yang besar berdasarkan saiz dan bentuk aneurism. Telah dibuktikan bahawa taburan tekanan yang kuat berlaku di kedua-dua pangkal dan sekitar bahagian pembengkakan aneurism. Dengan mengkaji sifat-sifat mekanikal di abdomen aneurism yang sebenar dapat memberikan maklumat-maklumat yang berguna kepada doktor-doktor kerana ini dapat menolong mereka untuk lebih memahami keadaan aneurism.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The aorta is the largest artery in our body. It is the main artery of the body, supplying oxygenated blood to the circulatory system. In human body, it passes over the heart from the left ventricles and runs down in front of the backbone. The aneurysm then is an excessive localized swelling of the wall of the artery. The force of blood pushing against the weakened or injured walls can cause bulges and fill it with blood. Then it will become abnormally large its look like the balloons outward. However, certain medical problems, genetic conditions, and trauma can damage or injure the artery walls. The biomechanics of aneurysm has been studied with great interest since aneurysm rupture is a mechanical failure of the degenerated aortic wall and is a significant cause of death in developed countries (David A. Vorp. 2006).

In these recent years, the number of cases for aneurysm had increases. The study and research had been in hope to solve this problem. Patients are currently advised repair if the diameter of the AAA is 5.5 cm or when the aneurysm is symptomatic (A. K. Venkatasubramaniam et al 2004. The main complication of aneurysm is like compression of nearby structures such as nerves, which may lead to weakness and numbness. A blood clot can develop in the aneurysm because blood flow inside the aneurysm is sluggish. The clot may extend along the entire wall of the aneurysm. A blood clot may break loose, travel through the bloodstream, and block the arteries. Besides that, the infection can lead the body to wide illness. The greatest danger of an aneurysm is rupture, which is often a fatal event.

PROBLEM STATEMENT

Nowadays, the case of rupture of AAAs is increasing every years and it often occurs without any preceding symptoms. The rupture occurs when the stress acting on the aorta wall exceeds the strength of the aorta wall itself. It was necessary to establish reliable criteria of the rupture risk assessment procedures in AAAs for these lesions, and criteria based on the mechanical field. Besides that, the prediction of rupture happens is not available yet. The stress distribution caused by pressure in the aorta is one element factor that influenced the rupture of aneurysm. So it was necessary to study the behavior of these elements to better understanding of aneurysm.

1.2 PROJECT OBJECTIVE

The objectives of this study are;

- To study the computation of the wall stresses in each virtual of AAA.
- The investigation of finite element analysis with different geometries of AAA.
- Determine the effect of geometry that influence the magnitude and distribution of the peak wall stress in the aneurysm.

1.3 PROJECT SCOPE

This project is about to investigate the condition of patient with aneurysm with a certain softwares. In this type of study, only aneurysm from abdominal area were selected. A models of AAA with fusiform shape were created in 2-dimension modeling with differences kind of geometry. The studies being proceed without experimentally but only based on numerical approach. After the models were created, the finite element analysis on this models will be done. The result from this study will be analyze and be discuss.

1.4 THESIS ORGANIZATION

There are 5 chapters in this thesis and was organized as follow. For each chapter, there are sub-topics in it.

In the chapter 1, Introduction consists of some information about aneursym, the studies and the purpose of this study. In addition, this section also includes the objectives of the study, the scope of study, the project assumption and how this thesis is organized.

Chapter 2, Literature Review is to gather the useful information from journals, books and articles that are related to aneurysms study. All the information that gathered from this chapter will be reviewed to simulate the AAA.

Chapter 3, Methodology, is about the method to simulate this project. The details about how the simulation is running and the properties that had been used will be shown.

Chapter 4, Result and Discussion is about the analysis of collected data from the simulations. The behavior of result will be analyzed and discuss.

Chapter 5, Conclusion will discuss about the achievment of the study and also either the project objective is completed or not. The recommendation regarding the project for the benefits in the future study will be shared.

CHAPTER 2

LITERATURE REVIEW

2.1 BACKGROUND

AAA disease is degenerative process which worst event is the rupture of the vessel wall that can bring fatal effect. A.K.Venkatasubramaniam et al. (2004) study as cited in J.F. Rodriguez et al. (2008) shows that the peak wall stresses in the ruptured aneurysms were found to be about 60% higher than for the non-ruptured aneurysms. Surgically clipping the aneurysm from the outside cuts off the interior flow and prevents rupture, but invasive neurosurgery carries well-known risks of mortality and morbidity (G.R.Stuhne and D.A.Steinman, 2003). Along with this, the reliable method to predict AAA rupture is not available yet. In this field of study, the stress distribution of AAA in will be investigated using finite element analysis. Biomechanical studies had suggested that one determinant of AAA rupture is related to the stress in the wall (J.F. Rodriguez et al. 2008). By studying the stress distribution of AAA, the impact load that occurs that applied can be determine and more, it can predict when the rupture is happening. The basic approach of the finite element method is to divide a complex geometrical structure (AAA) into smaller pieces or elements (M. Truijers et al. 2007). The stress distribution on each element will be investigated to find better accurate analysis. Other than that, the data analysis is depending on real situation of AAA condition itself. There is some consideration should take into the account before the study is to proceed. Knowledge of the regional distribution of wall thickness and failure properties in an AAA can help in understanding its natural history, developing methods to predict rupture risk and in designing vascular prostheses (Madhavan L. Raghavan et al. 2006).

2.2 TYPES OF ANEURYSM

2.2.1 Abdominal Aortic Aneurysm

Abdominal aortic aneurysms (AAA) are aneurysms that occur in the part of the aorta that passes through the abdomen. Previous research by Fillinger et al (2002) as cited Steven P. Marra et al (2006) has demonstrated that aortic aneurysm wall stress is strongly associated with aneurysm rupture risk in AAA. This type of aneurysms may cause a pulsing sensation in the abdomen and when they rupture, it can causes deep and excruciating pain. Doctors often detect an aneurysm during an examination or imaging procedure that is done for another purpose. The drug is given to lower blood pressure and aneurysms that a large or growing are repaired by either open or endovascular stent-graft surgery.

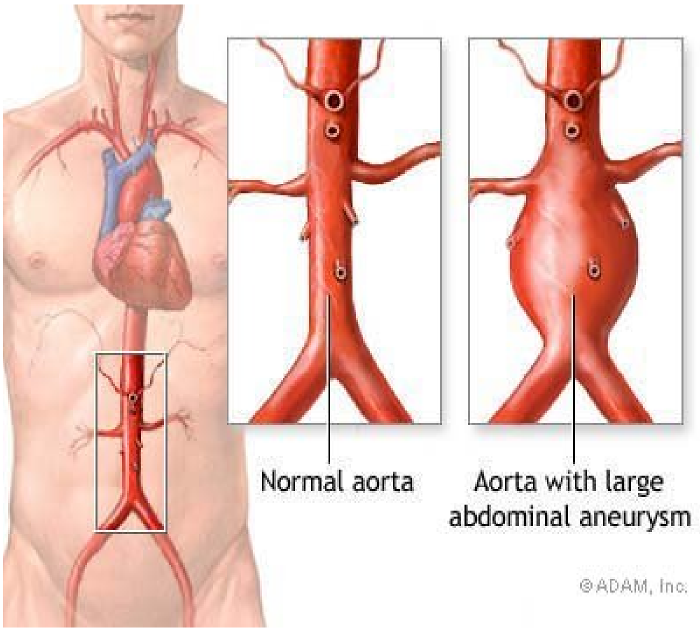

Figure 2.1: Abdominal aortic aneurysms

Source: http://health.allrefer.com

2.2.2 Thoracic Aortic Aneurysm

Thoracic aortic aneurysms are aneurysms in the part of the aorta that passes through the chest (thorax). It may not cause symptoms, or they may cause pain, coughing, and wheezing. Thoracic aortic aneurysm with vertebral erosion is a very rare and potentially fatal condition (Yosuke Takahashi et al. 2007).Thoracic aortic aneurysms are associated with a pathologic lesion termed "medial degeneration," which is described as a no inflammatory lesion and it was complication of Marfan syndrome and can be inherited in an autosomal dominant manner of familial thoracic aortic aneurysm **(**Rumin He MD et al. 2007). If an aneurysm ruptures, people may have excruciating pain that begins high in the back and spreads down the back and into the abdomen. Aneurysms are often discovered by chance, but doctors do x-rays, computed tomography, or another imaging procedure to determine the size. Rupture of an aortic aneurysm represents a life-threatening condition and most patients die within 6 h after rupture (Johansson G and Markstrom U, 2006)

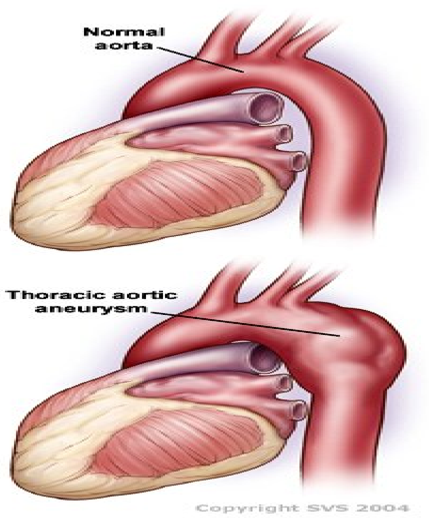

Figure 2.2: Thoracic Aortic Aneurysms

Source: http://www.vascularweb.org

2.2.3 Cerebral Aortic Aneurysm

A cerebral aneurysm occurs at a weak spot in an artery that supplies blood to the brain. Once weakened, the artery wall bulges outward and fills with blood. Most bifurcations of the cerebral vasculature are structurally stable, but a small number develop a weakness that causes the wall to expand outwards in the region near the flow divider of the branching artery (M.Kroon and G.A. Holzapfel, 2007). An aneurysm can burst, spilling blood into the brain. When this happens, permanent brain damage, disability, or death may occur. Most cases of cerebral aneurysm are caused by congenital factors. Congenital means that the person was born with the defect. These mean that person has artery walls that are thinner than normal in some places. It is in these regions that aneurysms develop. Aneurysms may be caused by other factors, as well. These factors include injury to the brain, infection and hardening of the arteries. Previous research by Thom T et al (2006) as cited by Xin Zhou et al (2006) shows that the rupture of cerebral aneurysm is the leading cause of hemorrhagic stroke and its mortality rate is about 3–4 folds than that of ischemic stroke within the onset of 30 days.

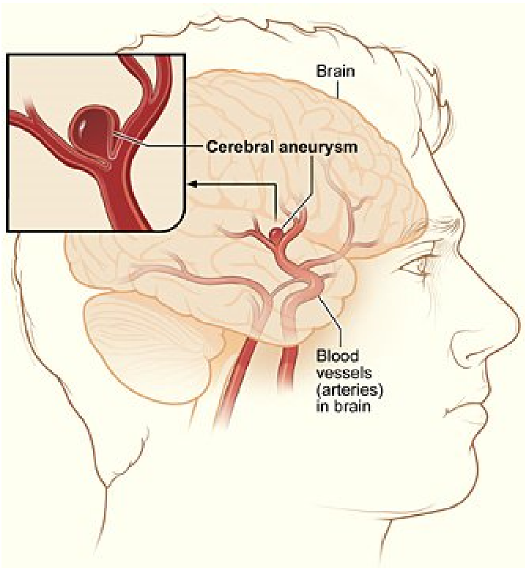

Figure 2.3: Cerebral Aortic Aneurysm

Source: http://www.web-books.com

2.3 RISKS OF ANEURYSM

It is not clear exactly what causes aneurysms. But some of these factors are the contributors to aneurysm. These factors causes the walls of the arteries to weaken thus lead to an aneurysm.

- Age
- Gender factor
- Hypertension
- Ischaemic heart disease.
- Smoking
- Chronic obstructive pulmonary disease

Aneurysms develop slowly over many years and often have no symptoms. Sometimes people do not realize they have an aneurysm that can lead to rupture. This symptoms usually happens to the area where aneurysm is occurs. The symptoms of rupture include:

- Headache
- Anxiety
- Clammy skin
- Nausea and vomiting
- Pain in the abdomen or back, severe, sudden, persistent, or constant. The pain may radiate to groin, buttocks, or legs.
- Ringing in the ears
- Pulsating sensation in the abdomen
- Rapid heart rate when rising to a standing position
- Shock

Table 2.1: Comparison of patient demographics between ruptured and non-ruptured AAA

Source: A. K. Venkatasubramaniam et al. 2004

	Non-ruptured AAA (n=15)	**Ruptured AAA (n=12)**	**P (*x*2)**
Age- median years (range)	75 (66–90)	75 (71–84)	NS
Sex- Male:female	5:1	5:1	NS
Hypertension (%)	67	25	NS
Ischaemic heart disease (%)	33	50	NS
Smoking (%)	33	57	NS
COPD (%	56	71	NS

COPD, chronic obstructive pulmonary disease. NS, not significant.

2.4 FINITE ELEMENT ANALYSIS (FEA)

Finite element analysis is a powerful computer-based tool widely used by engineers and scientists for understanding the mechanics of physical systems. Finite element analysis consists of a computer model of a material or design that is stressed and analyzed for specific results. Mathematically, the finite element analysis is used for finding approximate solutions of partial differential equations as well as of integral equations and in order to present unlimited degrees of freedom of structures by limited degrees of freedom, the structures are divided into many elements (Aihong (Rachel) Zhao et al. 2007). These elements are connected by joint called node and make a grid named mesh. Several modern finite element packages include specific components such as thermal, fluid flow, electrostatic and structural working environments

Generally, there are two types of analysis that is two-dimensional and three-dimensional analysis. The structural of finite element analysis usually consist either linear or nonlinear and it does generally characterize the elements. Usually finite element models contain tens of thousands and possibly hundreds of thousands of elements, resulting in hundreds of thousands of (simultaneous) equations (A.K.Venkatasubramaniam et al. 2004). Usefulness of the finite element analysis result depends highly on the pre-processing stage. Thus, defining an appropriate physical model such as mathematical model, geometrical simplifications, material properties, boundary conditions and an adapted mesh in accordance with simulation goals is a very difficult and time-consuming task. In practice, the modeling assumptions are still mostly based on the user's experience (E. Bellenger et al. 2008). By using this tool, it significantly improved both the standard of engineering designs and the methodology of the design process in many industrial applications.