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JUDUL: **THE EFFECT OF STENT VOID AREA ON HEMODYNAMICS IN CEREBRAL ANEURYSM**

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THE EFFECT OF STENT VOID AREA ON HEMODYNAMICS IN CEREBRAL ANEURYSM

SURIANI BINTI ABD RAHMAN

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

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We certify that the project entitled "*The Effect of Stent Void Area on Hemodynamics in Cerebral Aneurysm*" is written by *Suriani binti Abd Rahman*. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering. We herewith recommend that it is accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

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

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ABSTRACT

The purpose of this study is to develop modeling methodologies to understand how different stent void area alter the aneurysmal flow. Four difference stents design with difference void area were created with suitable geometry for Computational Fluid Dynamics (CFD) analysis. The velocity profile and pressure distribution after installing the device had been identified from the selected stent. These four types of design will be referred as stent type I, II, III, and IV and these stent was tested in an aneurysm model. The simulation of the model was studied under incompressible, Newtonian, viscous, non pulsatile condition. In this study, we need to determine the correlation between stent porous area and blood flow and to determine the flow behavior in stented aneurysm. We found the stent design affected a cerebral aneurysm hemodynamic. The different of stent structural pattern produces the different results of flow field around the stented aneurysm. The minimum velocity had improved after stents insertion and the type IV with less void area results most optimized. Other than that, the peak pressure will also decrease after the stent implantation. As expected, the lowest peak pressure results from stent type IV. The result shows that the stent with the lowest void area gives the best performance.

ABSTRAK

Tujuan kajian ini adalah untuk meningkatkan kaedah permodelan untuk memahami bagaimana keluasan stent yang berbeza mengubah pengaliran darah dalam aneurism . Empat rekabentuk stent dengan keluasan yang berbeza telah dihasilkan dengan geometri yang sesuai dianalisis menggunakan program dinamik bendalir tiga dimensi. Profil halaju dan taburan tekanan diperolehi hasil dari implant stent yang terpilih. Empat jenis rekabentuk stent yang dikaji ini dirujuk sebagai jenis I, jenis II,jenis III, dan jenis IV dan stent-stent ini telah dimasukkan ke dalam aneurism dan dianalisis. Simulasi model dikaji dengan parameter aliran mampat, Newtonian, bendalir likat dan keadaan tiada denyut menggunakan program dinamik bendalir tiga dimensi. Kami mendapati rekabentuk stent memberi kesan terhadap hemodinamik darah. Perbezaan struktur telah menghasilkan bentuk aliran yang berbeza disekitar aneurism. Halaju minimum telah di pertingkatkan selepas implant stent dibuat dan stent jenis IV yang mempunyai keluasan yang paling rendah mengahsilkan keputusan yang paling optimum. Selain itu, tekanan meksimum juga akan menurun selepas pemasangan stent. Seperti yang dijangka, tekanan maksimum yang paling rendah dihasilkan oleh stent jenis IV. Keputusan daripada kajian ini menunjukkan stent yang mempunyai keluasan terendah memberikan keberkesanan yang terbaik.

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LIST OF SYMBOLS

u_i : velocity in the *i*-th direction

P : pressure

f_i : body force

ρ : density

μ_i : viscosity

δ_{ij} : Kronocker delta

LIST OF ABBREVIATIONS

3DRA : Three-dimensional rotational angiography
AAA : Abdominal Aortic Aneurysm
CFD : Computational Fluid Dynamics
CT : Computer-assisted tomographic
DSA : Medical substraction angiography
FEFLO : Incompressible flow solver
GTA : Computer tomographic angiography
ICA : Intracranial aneurysm
LBM : Lattice-Boltzmann Method
MRA : Magnetic resonance angiography
MRI : Magnetic resonance Imaging
OSI : Oscillatory shear index
SPH : Smooth-particle hydrodynamics
TAA : Thoracic Aortic Aneurysms
TAWSS : Time-averaged wall shear stress
WSSG : Wall Shear Stress Gradient

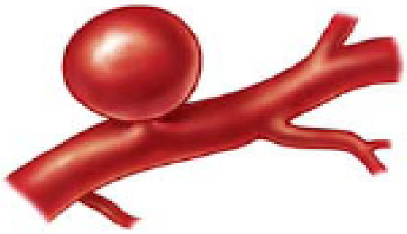
CHAPTER 1

INTRODUCTION

1.1 Aneurysm

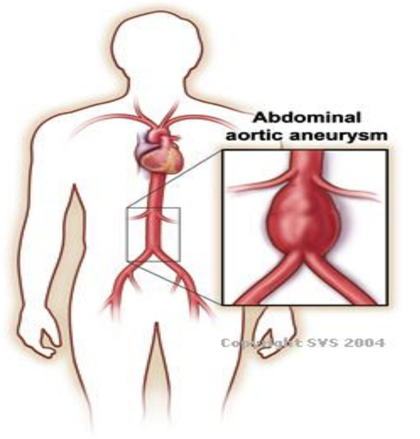
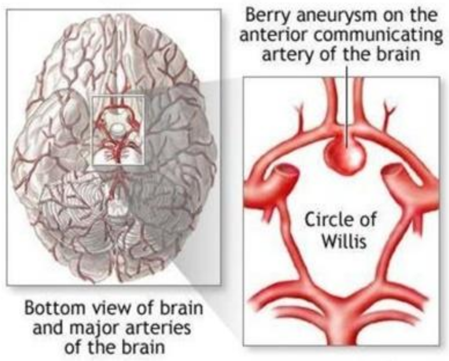
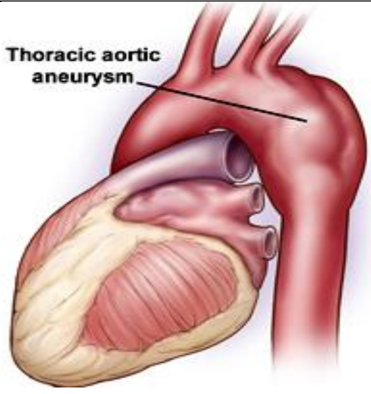
An aneurysm can be defined as a weak area in the wall of a blood vessel that causes the arteries to swelling or balloon out. Arteries are blood vessels that carry oxygen-rich blood from the heart to other parts of the body. An aneurysm that grows and becomes large enough can burst, causing dangerous, often fatal, and bleeding inside the body. Generally, aneurysms can be found either in saccular or fusiform shape as shown in Table 1.1.

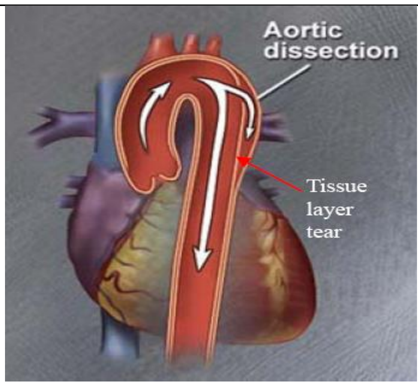
Table 1.1: General shape of aneurysm

No	Shape of Aneurysm	Figure
1	Saccular	
2	Fusiform	

There are several main types of aneurysm which are cerebral aneurysm, thoracic aortic aneurysm, abdominal aortic aneurysm (AAAs), and dissecting aortic aneurysm as summarized in table 1.2

Table 1.2: Types of aneurysms

No	Type	Figure
1	Abdominal Aortic Aneurysms (AAAs). (Source: http://www.mayoclinic.org)	
2	Brain aneurysms. (Source: 2001 eCureMe.com)	
3	Thoracic aortic aneurysms (Source: http://www.vascularweb.org)	

4	Dissecting aortic aneurysms (Source: http://www.mayoclinic.org)	

For this project, I will focus on cerebral aneurysm type. A cerebral aneurysm can be defined as a weak or thin spot on a blood vessel in the brain that balloons out and fills with blood. The bulging aneurysm can put pressure on a nerve or surrounding brain tissue. It may also leak or rupture, spilling blood into the surrounding tissue. Some cerebral aneurysms, particularly those that are very small, do not bleed or cause other problems. Cerebral aneurysms can occur anywhere in the brain, but most are located on the arteries at the base of the brain. That part is known as the Circle of Willis. To detect cerebral aneurysm, there are few tests that can be used such as Computerized Tomography (CT scan), CT Angiography, X-Ray, Magnetic resonance imaging, and Carotid & Vertebral digital substraction angiography.

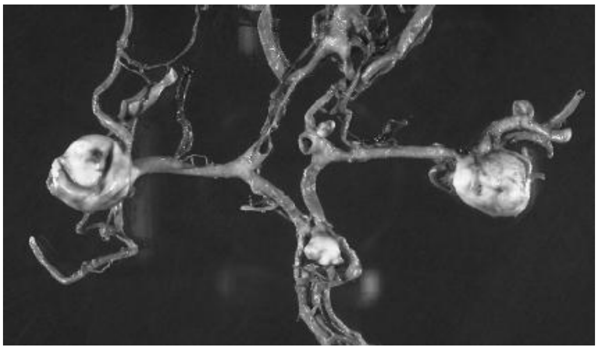


Figure 1.1: CT scan image of cerebral aneurysm

(Source: http://www.ninds.nih.gov)

Figure 1.2: Brain Aneurysm detected by X ray

(Source: http://www.faqs.org)

Cerebral aneurysms can be classified due to its size and shape. Small aneurysms have a diameter of less than 15 mm. Larger aneurysms include those classified as large (15 to 25 mm), giant (25 to 50 mm), and super giant (over 50 mm). Usually, cerebral aneurysm may occur because of a weakness in the blood vessel wall that is present from birth. Other than that, the causes of cerebral aneurysm also include high blood pressure that has been occur over many years resulting in damage and weakening of blood vessel, tumors, trauma or injury to the head, smoking, and drug abuse. Normally, there may be some symptoms that will experienced by the patient of this diseases which are nausea and vomiting, extremely severe headache, loss of consciousness, stiff neck, and hyper tension (high blood pressure).

Nowadays, there are three methods used in treatment of cerebral aneurysm which are surgical clipping, Endovascular embolization, and endovascular aneurysm repair.

Surgical clipping was introduced by Walter Dandy of the john Hopkins Hospital in 1937. It consists of performing a craniotomy, exposing the aneurysm, and closing the base of the aneurysm with a clip. The surgical technique has been modified and improved over the years. Surgical clipping remains the best method to permanently eliminate aneurysms. Depending on the shape and location of the aneurysm, surgical clipping has been a very effective treatment, and typically, aneurysms that have been completely clipped do not recur. Surgical clipping minimizes the necessity for periodic follow-up angiographic studies. Furthermore, surgical clipping provides controlled access to difficult anatomy and allows for arterial reconstruction when aneurysms have complicated shapes and wide necks. Typically, aneurysm clips are made from titanium. Titanium is selected because of their characteristics which are strong, has a low density, and has a highly corrosion-resistant metal alloy. The clip has a spring mechanism that allows the jaws of the clip to be placed on the aneurysm neck, thus occluding the aneurysm from the feeding blood vessel. Figure 1.3 shown the variety of aneurysm clips and Figure 1.4 shown a titanium clip is placed across the neck of an aneurysm.

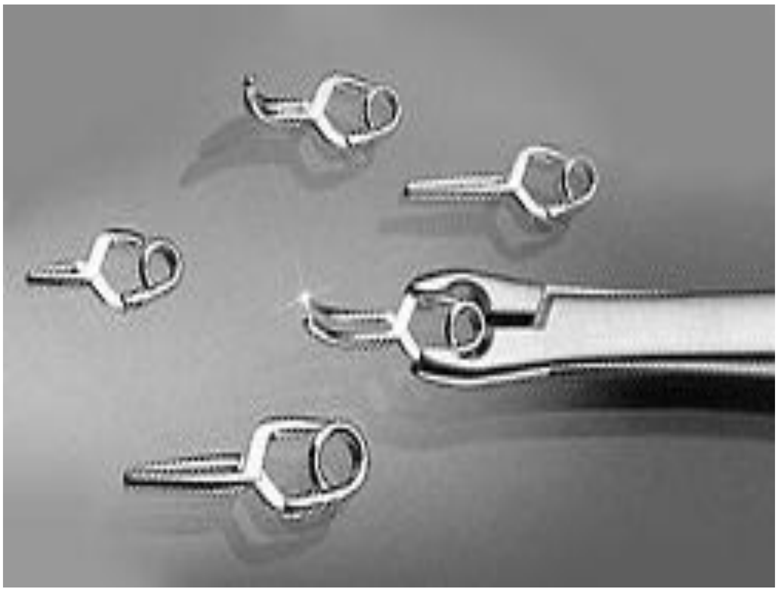


Figure 1.3: Variety of aneurysm clips

(Source: http://www.mayfieldclinic.com)

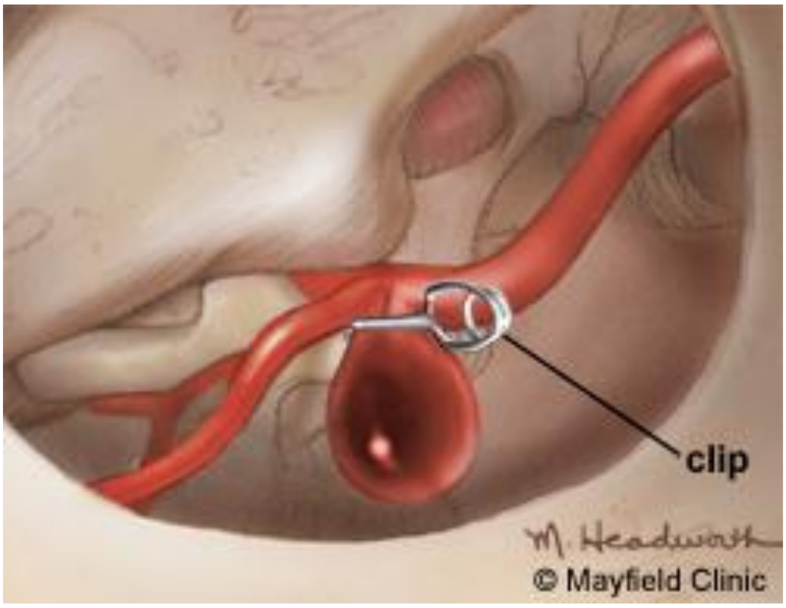
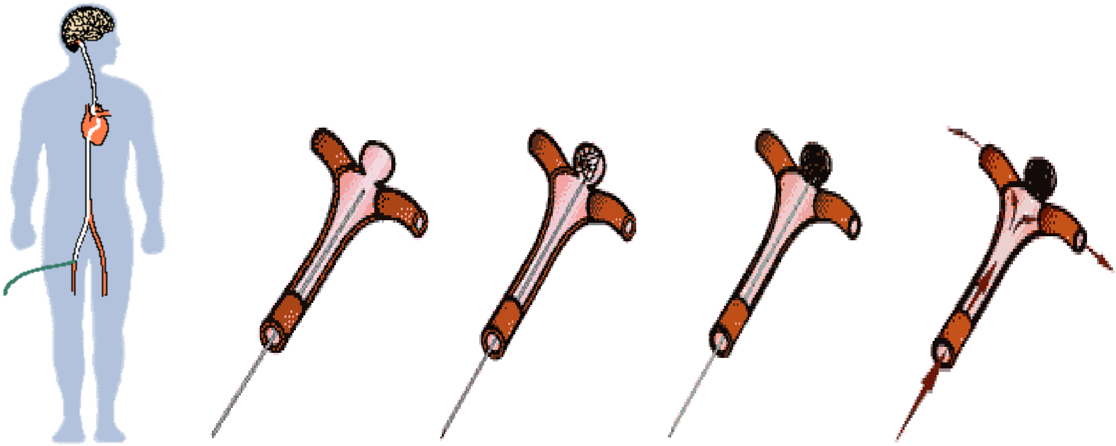


Figure 1.4: A titanium clip is placed across the neck of an aneurysm

(Source: http://www.mayfieldclinic.com)

Endovascular embolization is an alternative to surgery. This treatment has been offered at Toronto Western Hospital since 1992. This is done in the neuroangiography suite under fluoroscopy. The Neurointerventional radiologist will make a small incision in the groin through which a tiny catheter is guided through the femoral artery into the brain vessels (1st stage). The catheter is carefully guided into a site of aneurysm (2nd stage). Soft platinum coils are deposited through the microcatheter into the aneurysm (3rd stage). When in this position, the coil is released by an application of a very low voltage current causing the coil to detach from the pusher wire. The softness of the platinum allows the coil to conform to the often irregular shape of the aneurysm. An average of 5-6 coils are required to completely pack an aneurysm (4th stage) The goal of this treatment is to prevent the blood flow into the aneurysm sac by filling the aneurysm with coils and thrombus (5th stage). This treatment would prevent the aneurysm bleeding or re-bleeding.



(1st stage) (2nd stage) (3rd stage) (4th stage) (5th stage)

Figure 1.5: Process of Endovascular Embolization

(Source: http://brainavm.oci.utoronto.ca)

For the third method used for treatment aneurysm is endovascular repair. This method involves strengthening the blood vessel wall with an expandable metallic stent. Stent implantation is relatively new and being more implemented over open surgery. There are some examples of implantation of stent in thoracic aneurysm and AAA as shown in figure 1.6 and 1.7. The process of endovascular repair can be seen in figure 1.8.

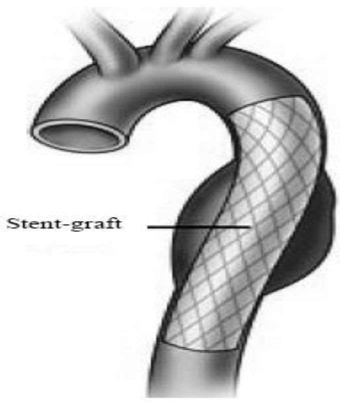


Figure 1.6: Stented Thoracic

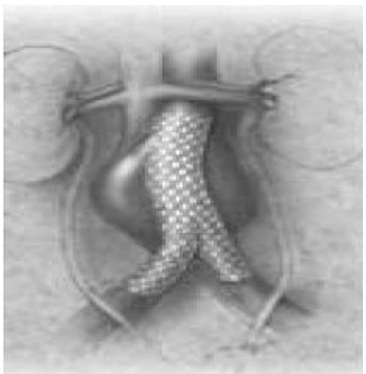


Figure 1.7: Stented AAA

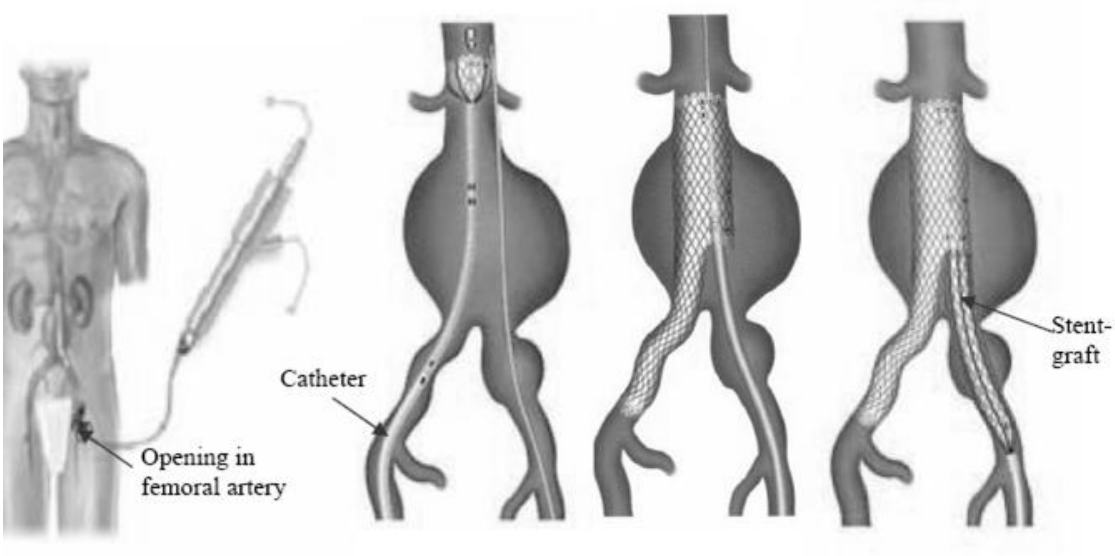


Figure 1.8: Process for endovascular repair

(Source: http://www.hpcbd.com)

1.2 Stent technology

Stent is a wire metal mesh tube inserted into a weakened area in a blood vessel to help the blood flow smoothly and avoid aneurysm from burst. There are two types of stents: bare stents (wire mesh) and covered stents (also commonly called stent grafts). As many as 30 different stent designs are in use in the world. Stents may be classified based on their predeployed repeating 'cell' pattern of metal construction (slotted tube, coil, or mesh) and nature of the stent delivery systems (self-expandable or balloon-expandable). With the abundance of new stents, there is an urgent need for a how to manual to help interventional cardiologist through the plethora of stent brands, types, structures, patterns, strengths, diameters and lengths.

Currently, a stent classification design was proposed by Jost which was based on structural characteristics of the stents. This includes original slotted tube stents (eg. Palmaz-Schatz) as shown in figure 1.9, second generation tubular stents such as Crown, MultiLink, and NIR, self-expanding stents such as Wallstent and Tristar stents, coil stents such as Crossflex and Gianturco-Roubin, and Modular Ziagzag stents (eg. AVE GFX).

In general, slotted-tube systems, characterized by the PT stent, are characterized by Palmaz-Schatz stent, characterized by high vessel surface area coverage, high radial strength, and consistent circumferential deployment pattern. Coil stent provide for greater flexibility, conformability to the target vessel tortuosity, and access to side-branches but have significant intrinsic recoil. Mesh design stent, found in many of the second generation tubular stents, are hybrid of slotted tube and coil features. They possess the sizing strategies and deployment mechanics of slotted tube stents; and flexibility, conformability and side-branch access of the coil stents. A summary of current stent designs is shown in Table 1.3. (H C Tan, Y T Lim, 1999). The figure of linkage example shows in Figure 1.9.

Table 1.3: Current stent design

Type	**Product Name**	**Material**
Self expanding stents	Wallstent Radius	Cobalt alloy Nitinol
Balloon expandable	Gianturco-Roubin	Stainless steel
Coil stents	Crossflex Wiktor	Stainless steel Tantalum
Balloon expandable	Palmaz-schatz	Stainless steel
Tubular stents	Crown NIR MultiLink Bestent	Stainless steel Stainless steel Stainless steel Stainless steel
Balloon expandable	Crossflex LC	Stainless steel