

Examining the flow of blood in the case of a cerebral aneurysm

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Abstract

The aim of the project is to apply a CFD approach to the flow of blood through a cerebral aneurysm which enables the different interactions to be studied in detail. From this study, one hopes to be able to propose to surgeons a more refined and safer method to tackle this condition and to improve the success rate during real time operation. It has been put in place two main orientations by INRIA in collaboration with ICAM in order to resolve the issues of the aneurysm. The suggested methods are as follows:

To measure the spread of blood flow by injection of a contrast within the flow and using X ray pulses which take pictures at a rate of 30image/second. This provides a visual perspective of the blood flow inside the area of interest. Furthermore, the computer based model will provide parameters as a base for the fluid mechanics calculations.

To study different models that already exist to combat the aneurysm in order to carry out simulations on the model of the vascular network in silicone. Various simulations on the reconstructed vascular network model in silicone will be carried out.

Nomenclature

C.A Cerebral Aneurysm
VMG Voxel model generator
 ρ Density of blood

Introduction:

[2] Cerebral aneurysm is the inflammation of the wall of an artery in the brain. This produces a sac of a few mm in length embedded within the cranial area. Unfortunately this condition can only be surpassed with intensive surgery which at the moment has a low success rate as knowledge of the condition is limited. C.A can be hereditary, so it's to say that the parents which carry the condition and undergo surgery to extract it, there's still a great likelihood that the child of the affected parent could have the condition emerging in the brain. C.A's are also more common in people with certain heritable diseases, such as connective tissue disorders and polycystic kidney disease. Amongst the genetic diseases, there are some circulatory problems associated with the C.A, such as arteriovenous malformations (tangles of arteries and veins in the brain that disrupt blood flow).

Other causes in which a C.A is produced are trauma's or injuries to the head, high blood pressure, infection, tumors, atherosclerosis (a blood vessel disease in which fats build up on the inside of artery walls also be worsened by smoking) and other diseases of the vascular system. Aneurysms that result from an infection in the arterial wall are called mycotic aneurysms.

Cancer-related aneurysms are often associated with primary or metastatic tumors of the head and neck. The habitual use of cocaine can inflame blood vessels and lead to the development of brain aneurysms. Statistics show that C.A is more common in adults than in children and are slightly more common in women than in men. The problems that the C.A poses for a surgeon and a patient are signs and symptoms are solely dependent on the size and rate of growth. The longer the aneurysm the higher the risk if rupture. There are three types of C.A. A saccular aneurysm is a pouch-like sac of blood that is attached by a neck and protrudes out of an artery or a branch of a blood vessel.

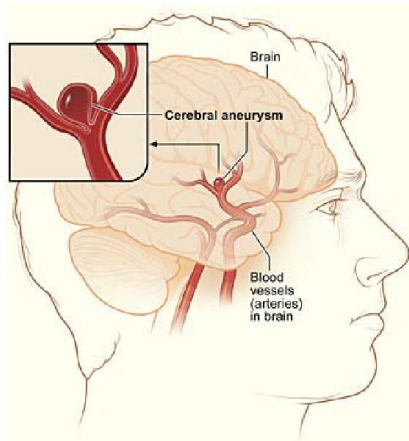


Figure 1: Diagram of a C.A in the brain [1]

The second type of C.A is a lateral aneurysm. This appears as a bulge on one wall of the blood vessel, while a fusiform aneurysm is formed by the widening along all walls of the vessel. C.A's can also be classified by size. Small C.A's are less than 11 millimeters in diameter, and larger aneurysms are 11-25 millimeters. The largest C.A's are greater than 25 millimeters in diameter. It's possible for an average healthy middle aged man to be carrying the aneurysm but be asymptomatic to the fact that it exists as it will emit no visible or noticeable indications. However, a large aneurysm which is steadily growing may produce symptoms such as loss of feeling in the face or problems with the eyes. The growing C.A will eventually rupture and that's the principal concern associated with this study. The walls are really emaciated which increases the chance of rupture and therefore the surgeon's task becomes harder. Once the rupture has occurred, its know that the patient will feel nausea, visual impairment and even loss of consciousness. What this study aims to accomplish is a more refined method to tackle the problem and to be proposed to surgeons to increase the success rate during operations.

Brain surgery and CFD meshing:

The biggest problem that surgeons face with brain procedures is that the surgeons cannot see the structure where they have to put the electrode and, as a result, they must spend a considerable amount of time searching for it.

The only way they target the region can be identified is by its electrical characteristics. Surgeons must first insert an electrode and monitor the electrical activity of the neurons that it touches. Sometimes they have to remove and reinsert the electrode two or more times. Sometimes they have

to insert three or four electrodes at the same time in order to find the elusive spot. Every time the surgeon introduces the electrode, it increases the risk of damage to the brain and evidently to the C.A. When surgeons see that they have found the right spot, they implant a stimulating electrode to determine if it reduces the patient's symptoms. Operations can take as long as eight to 12 hours to properly extract the aneurysm.

The computer-aided guidance system compensates for variations in the three-dimensional brain structure of each patient, something that it is very difficult for surgeons to do on their own. This reduces operating times by increasing the odds that the surgeons begin searching closer to the target. To predict the location of the target area in a new patient, the researchers map the reference atlas onto the patient's brain scan. When the neurosurgeons have used the system's predictions, they have hit the target area on the first insertion two out of three times, compared with one out of five times when working without it.

To generate blood flow simulator, meshing is required the model the C. A. This meshing must be done properly and accurately to achieve high precision results. A complex piece like C.A will require dense meshing around the aneurysm to get a good ideas of what's going on inside. Unfortunately, meshing requires a very powerful machine and even with that it still takes a long time to generate a good quality mesh. Technical advances have allowed the meshing process to be eliminated. A VMG was created which abolishes the need for meshing but still maintains the same amount of accuracy. In normal blood flow simulations, surface models of blood vessels were constructed of tetrahedral and hexahedron shaped meshing. For complex shapes like the C.A., a more refined meshing was needed to take care of the tricky areas where the existing meshing will not produce the defined results that are needed in an intricate subject such as this one. The VMG uses meshing that divides the calculation area in into orthogonal shapes

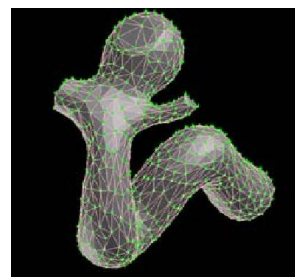


Figure 2: the Mesh of the model of Cerebral of Aneurysm

Endovascular Coil Embolisation

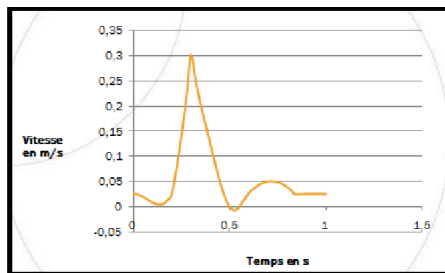
It exists 3 different methods to provide permanent solutions to the C.A. Firstly the *Microvascular clipping method*. This process involves cutting off the flow of blood to the C.A. whilst the patient is under anesthetic, a section of the skull is removed and the aneurysm is located. On the blood vessel that feeds the aneurysm, a small metal clip is fastened on the C.A's neck immobilizing its blood supply. The clip remains in the person and prevents the risk of future bleeding. The piece of the skull is then remounted and the scalp is closed. A similar procedure is an *occlusion*. In this case, the surgeon clamps (occludes) the entire artery that leads to the C.A. This procedure is often performed when the aneurysm has damaged the artery. The surgical method in question is to tackle the C.A is endovascular coil embolisation. This is the process in which a thin plastic tube called the catheter is initiated into the circulatory system by a major artery with a small incision in the groin area. Under X-ray guidance, the plastic tube is guided up to the C.A. Once there, platinum coils are guided through up to the C.A. The coils have a diameter of 0.25mm and lengths of around 20 to 300mm, depending on the size of the C.A will depend on the size of the platinum coil used. These are then fed in to the tube up to the C.A to fill the space. They start to wrap themselves around each other forming coils eventually; there will be a network of coils which will fill the space inside the C.A. The several coils within confined spaces promote the sluggish movement of blood and ultimately cause the blood to stagnate. The blood will subsequently thrombosis on the coils.

The initial values that will be implemented into the meshing system are the ones which resemble a real life C.A.

The density of the blood $\rho=1050\text{Kg/m}^3$

The viscosity of blood $\mu=0.0032\text{ Kg/ms}$

Figure 3: Showing the calculations



One pulsation : The inlet velocity as a function of the time.

Results

With the given data from INRIA, the boundary conditions were implemented into fluent and the following results were as shown.

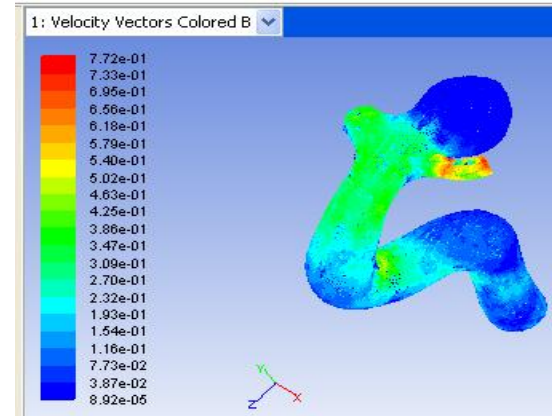


Figure 4: Visualisation of the velocity at 0.2 m/s throughout the aneurysm

At 0.2m/s, the velocity change is greater than what the results demonstrated at a lower speed. The flow seems to demonstrate turbulent features in the vein although It's in laminar flow as the Reynolds's number indicates. The sudden change in flow velocity will as a result, increase the shear stress and could lead to rupture.

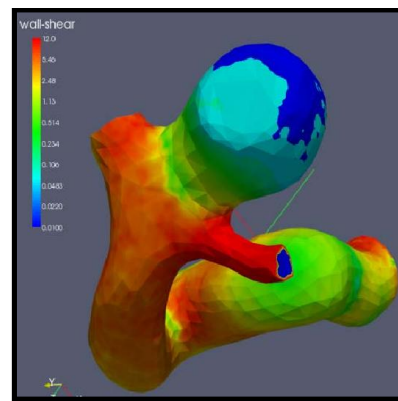


Figure 5: Wall shear in case of the same boundary conditions at outlet with the same flow rate [5]

The shear stress is noticed to be elevated in the region of the small exit as the velocity is increased. Beyond this limit is seems that rupture is likely.

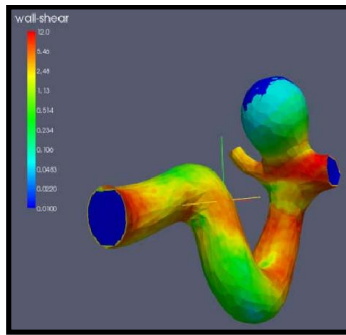


Figure 6: Wall shear in case of the same boundary conditions at outlet with different flow rate

Conclusion

In conclusion, the coil embolisation method is probably the most effective way to solve the problem. It allows the minimal of pain and risks and has a good success rate. The control of the shear stress is vital as this will determine the susceptibility to rupture of the aneurysm. From what has been established, a means of slowing down blood flow during the operation to reduce the amount of shear stress which will decrease the risk to rupture operations. The technological advances in cfd has made it viable now to recreate real conditions within the human body in order to make predictions and provide a better picture of what could possibly happen.

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