January 2, 2024

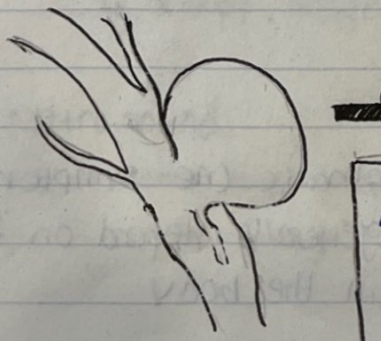
Aneurysms

↳ An abnormal bulge/ballooning in the wall of a blood vessel which results in the width of the vessel increasing in width by over 50%.

- Aneurysms can occur in any blood vessel, but they are most often seen in an artery rather than a vein

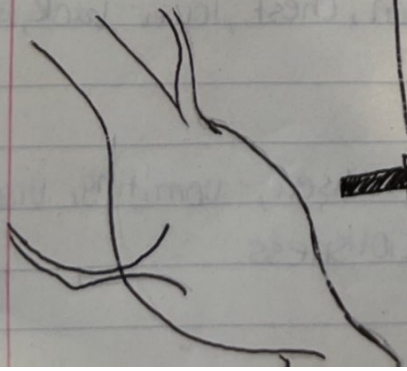
  ↳ They can be located in many areas of the body including blood vessels of the brain, the aorta, the neck, the intestines, the kidney, the spleen and the vessels in the legs. Most common location is in the aorta. (vessel that carries oxygenated blood from the heart to the body)

Shape



→ Saccular Aneurysm

- The shapes of an aneurysm helps identify if it is a true one. The saccular and Fusiform are the shapes an aneurysm takes form in, the fusiform one being the more common aneurysm.



→ Fusiform Aneurysm

Aneurysms

January 2nd, 2024

Causes

↳ Multiple factors can cause an aneurysm that result in the breaking down of the structural components (proteins) of the aortic wall, however the exact cause isn't fully known

① High blood pressure (Hypertension)
   ↳ most common cause of a rupture as a higher blood pressure makes blood push harder against blood vessel walls

② Weakness in blood vessel (present from birth)

③ older age

④ genetics

⑤ Elevated fats and cholesterol in the blood (Hyperlipidemia)

Symptoms

↳ Aneurysms can be asymptomatic (no symptoms) or symptomatic. Symptoms generaly depend on the location of the aneurysm in the body

EXAMPLES

↳ Abdominal Aortic Aneurysm (AAA):
   - constant pain in abdomen, chest, lower back, etc.

↳ cerebral Aneurysm
   - sudden severe headache, nausea, vomiting, visual disturbance, loss of consciousness...

January 4th, 2024

How are aneurysms diagnosed?

- Computed tomography (CT or CAT) scan
  - ↳ combination of x-rays and computer technology to produce horizontal, or axial, images (slices) of the body. CT scans are more detailed than x-rays

- Magnetic Resonance Imaging (MRI)
  - ↳ produces detailed images of organs and structures within the body

- Echocardiogram (echo)
  - ↳ evaluates the structure and function of the heart by using sound waves

- Arteriogram (angiogram)
  - ↳ X-Ray image of the blood vessels

- Utra sound
  - ↳ uses high-frequency sound waves and a computer to create images of blood vessels, tissues and organs

January 4th, 2024

TREATMENTS

- Specific treatments are determined based on:
  - ↳ age, overall health, medical history, extent of the disease (location, size and growth rate), signs and symptoms, tolerance of specific medications, procedures or therapies, and your opinion/preference

↳ Routine Ultrasound procedures
- monitors size and rate of growth ("watchful waiting" approach for smaller aneurysms)

↳ controlling or modifying risk factors
- steps like quitting smoking, controlling blood sugar if diabetic, losing weight if overweight, etc. may help to control the progression of the aneurysm

↳ Medication

↳ surgery
- Aneurysm open repair → incision made to directly visualize and repair the aneurysm

- Endovascular aneurysm repair (EVAR) → a procedure that only requires small incisions along with the use of x-ray guidance and specially-designed instruments to repair the aneurysm.

January 5th, 2024

Key words in literature reviews

WSS - Wall Shear Stress
- High WSS leads to aneurysm initiation and growth
- low WSS leads to growth alone

↳ frictional force of the blood on a vessel wall
- expressed in units of force per unit area [N/m^2 or Pascal (Pa) or dyn/cm^2 where $1\ N/m^2 = 1\ Pa = 10\ dyn/cm^2$]

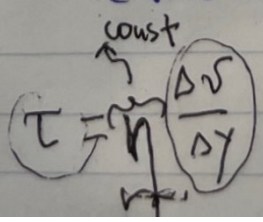
- WSS magnitude typically ranges from 0.1 to 0.6 Pa in the venous system and from 1 to 7 Pa in straight vessels of the arterial system.

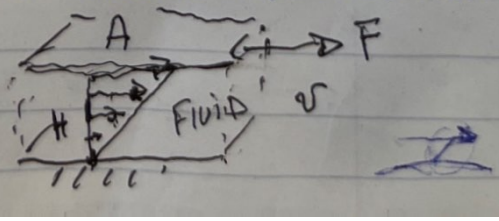
- Low WSS is considered to be < 1 pa

* OSI - oscillatory shear index
↳ used to describe the disturbance of the flow field in the aneurysm wall

Shear rate
↳ the rate of change in velocity at which one layer of fluid passes over an adjacent layer

Newtonian model
↳ describes the simplest type of flow behavior, namely that the material's viscosity is constant, independent of the applied shear rate
↳ fluid is one whose viscosity is not affected by shear rate





January 5th, 2024

Computational fluid dynamics simulations of CA using Newtonian, power-law... blood viscosity models

- **Newtonian fluids** are those that obey Newton's law of constant viscosity. (constan viscosity and zero shear rate at shear stress)

- **Non-Newtonian** fluids are fluids that do not have a constant viscosity and have a variable relationship with shear stress

January 6th 2024

Rare Aneurysms

>The 3 rarest types of aneurysms are the mycotic aneurysms, pseudoaneurysms and blister aneurysms.

Mycotic Aneurysms (Infection aneurysm)

↳ the expansion of the arterial wall due to infection. It happens when bacteria or fungi infect the wall of the blood vessel which causes the wall to weaken. Out of all aortic aneurysms, the mycotic ones only make up approximately 1-3%. → commonly caused by bacterial infections.

Pseudoaneurysms

↳ These types of aneurysms occur when the wall of a blood vessel becomes injured. The blood that leaks from the vessel then collects in the surrounding tissue. These aneurysms can also be known as "fake" aneurysms. They are different from true aneurysms because a pseudoaneurysm only includes 1 layer (or 2 max) of the artery wall whereas a true aneurysm includes all 3

Blood Blister aneurysm

↳ occurs in 0.3-1% of all intracranial aneurysms and 0.9-6.5% of ruptured aneurysms. They are difficult to treat because they originate from the non-branching sections of the supraclinoid portion of the Internal Cartoid Artery (ICA) unlike saccular aneurysms. These aneurysms make up 2% of all intracranial aneurysms.

Lesion → abnormal change in tissue of an organism
Supraclinoid portion → segment between the ophthalmic and Posterior-Communicating arteries

January 8th, 2024

infrarenal
↳ abdomen just below the kidneys

Lit. Review
Key words/meaning
↳ Atherosclerosis
↳ thickening or hardening of the arteries

Abdominal Aortic Aneurysms (AAA)

> AAAs occur in up to 9% of adults older than 65 years of age. 15000 deaths are caused by the rupture of these aneurysms in the US. annually.
- a healthy infrarenal aorta has a diameter of approximately 2 cm. An aortic diameter of 3cm or more is defined as an aortic aneurysm. Surgical or endovascular repair of an AAA is required when the diameter of the aneurysm reaches or exceeds 5.5cm, when the growth rate is faster than 0.5 cm in 6 months or when it is symptomatic.

> AAAs are the most common aneurysm of large arteries
> more common in males than females
> the commonness of an AAA is 3% in individuals older than 50 and 10% in males older than 65

Diagnosis

- Abdominal Ultrasound → most common test for diagnosis
- Abdominal CT scan → uses x-rays to create cross-sectional images of the structures inside the belly-area

- Abdominal MRI → Uses a magnetic field and computer-generated radio waves to create detailed images.
  * During some CT and MRI scans, a liquid called contrast may be inserted into the vein to make blood vessels show up more clearly on the images

January 10th, 2024

beta blockers
↳ a medication that decreases high blood pressure

Propranolol
↳ medicine called beta blocker

cont'd

Abdominal Aortic Aneurysms

Sizes/classification

Small aneurysms → less than 5cm in diameter
Medium aneurysms → 5-7cm
Large aneurysms → more than 7cm in diameter

STATISTICS

Occurence of rupture → between 5.6 and 17.5/100,000 individuals per year
(ruptured) general mortality rate → 80% - 90%
* noted that the rate of rupture and mortality could surpass 60% within 3 years of initial diagnosis, therefore early diagnosis/ surgical and/or medical intervention is essential to avoid rupture

MEDICINE (based) TREATMENT

- several non-surgical methods have been studied regarding the treatment/ management of AAAs. Several anti-inflammatory medications (statins, doxycycline and roxithromycin) as well as anti hyperintensive agents (i.e beta-blockers and diuretics) have been tested in hopes of obtaining the ability to limit the expansion rate of a small AAA. However, beta blockers have shown no significant effect on the growth rate of AAAs. Clinical trials have been run with a dropout rate of 40% in the propranolol group, proving that this method should not be further used in the prevention of small AAAs.

- Statins have shown to slow the progression rate of AAAs as this type of aneurysm has shown to increase the risk of cardiovasc complications as a result of atherosclerotic manifestations (thickening or hardening of the arteries) in the vascular area. In 5 years the mortality rate of AAAs is 25%, mainly caused by cardiovascular events. Statins have shown to be able to slow [illegible] and lower the mortality →

January 10th, 2024

AAA treatment (main surgical methods

rate by up to 43% in a 5-year period. Statins have even shown to slow the growth rate of AAAs as they reduce inflammation of vascular walls as well.

SURGICAL METHODS

Main types: Open repair and endovascular aneurysm repair

Open repair: a large incision is made in the abdomen to get a clear view of the aortic aneurysm. Once the abdomen is open, the aneurysm will be repaired using a graft (a long cylinder-like tube). These grafts are made out of a variety of materials, such as polytetrafluoroethylene (PTFE, a non-textile synthetic graft) or Dacron, a textile polyester synthetic graft. The graft is stitched to the aorta, connecting one end of the aorta located in the aneurysm site to the other end of the aorta.

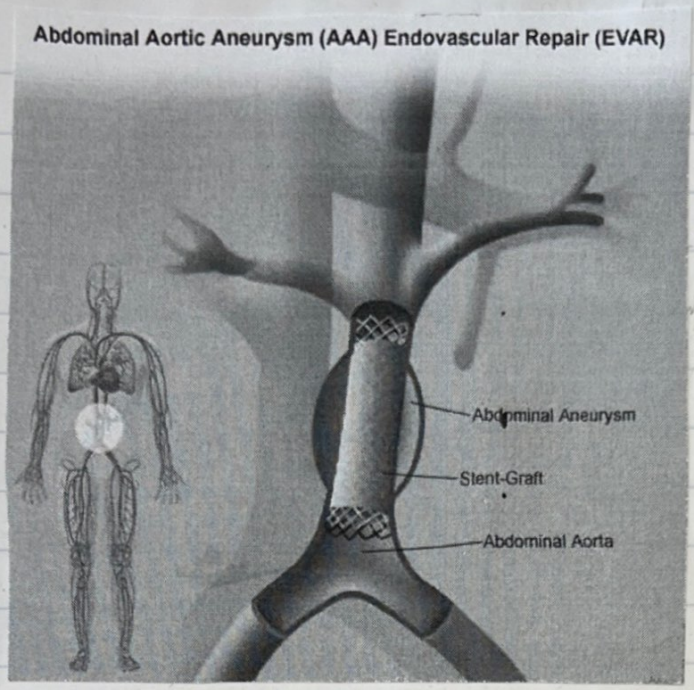
Endovascular aneurysm repair: A less invasive procedure for the repair of an aneurysm as the procedure is done from within the blood vessel without the use of open surgery. The aneurysm is excluded from blood circulation with the use of a device called an endograft. The endograft travels to the site of the aneurysm with the use of a catheder that is inserted into an artery in the groin. The catheder is carefully guided to the site of the aneurysm, the surgeon using a moving x-ray to monitor the catheder and making sure it gets to the right spot. A stent graft is sent along the catheder to the aneurysm. The stent graft is collapsed so it is narrow and can fit through the blood vessel. When the stent graft reaches the aorta, it is opened up and fastened in place. The stent graft then stays in place and blood flows through it → protects aorta and prevents bursting

stent graft
↳ tube made of a thin metal mesh (the stent) covered with a thin layer polyester fabric (the graft)

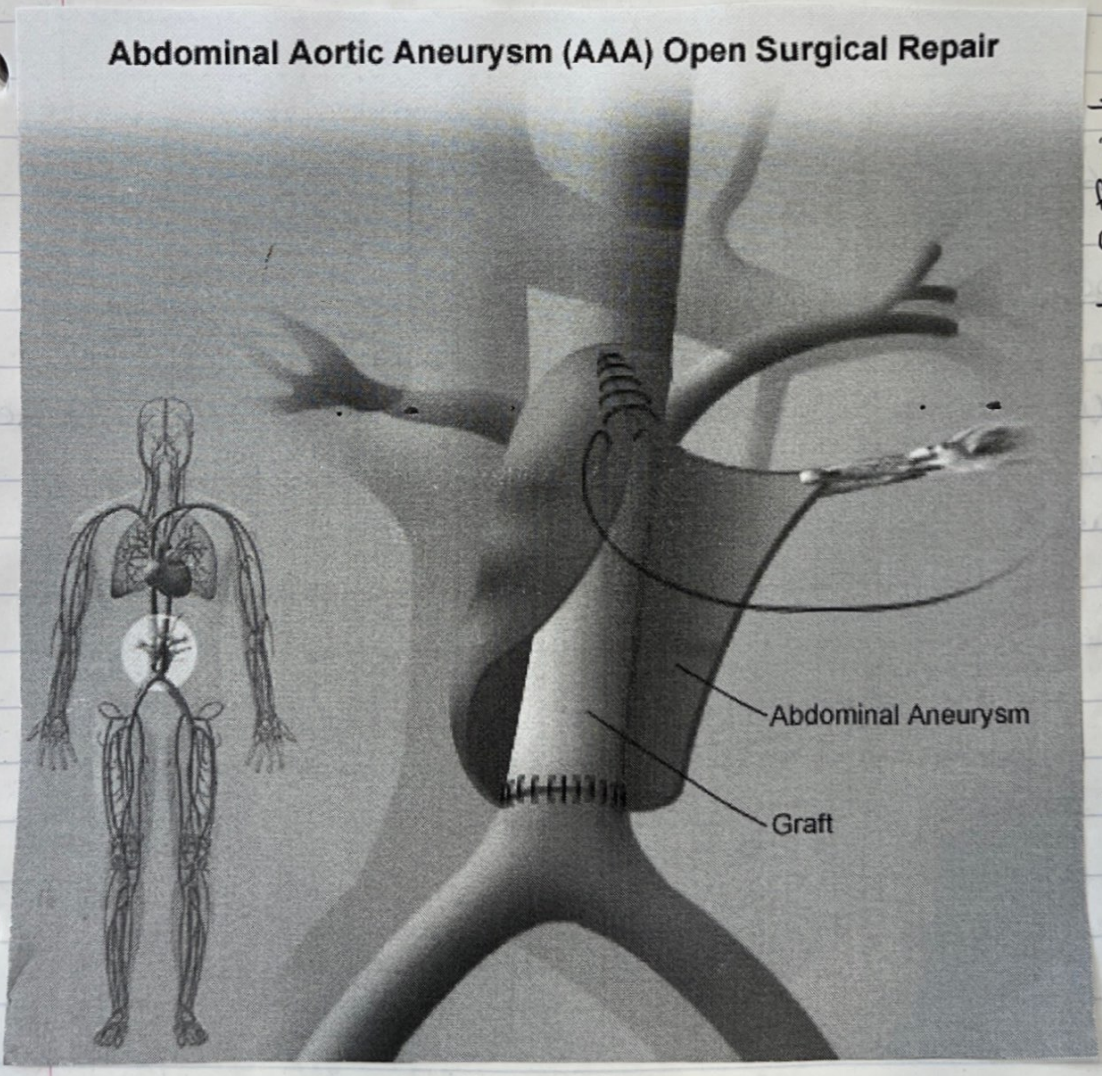
January 11th, 2024

Surgical methods for AAA treatment

Things done today:
- worked on research ? lit review
- found and printed pictures ↓



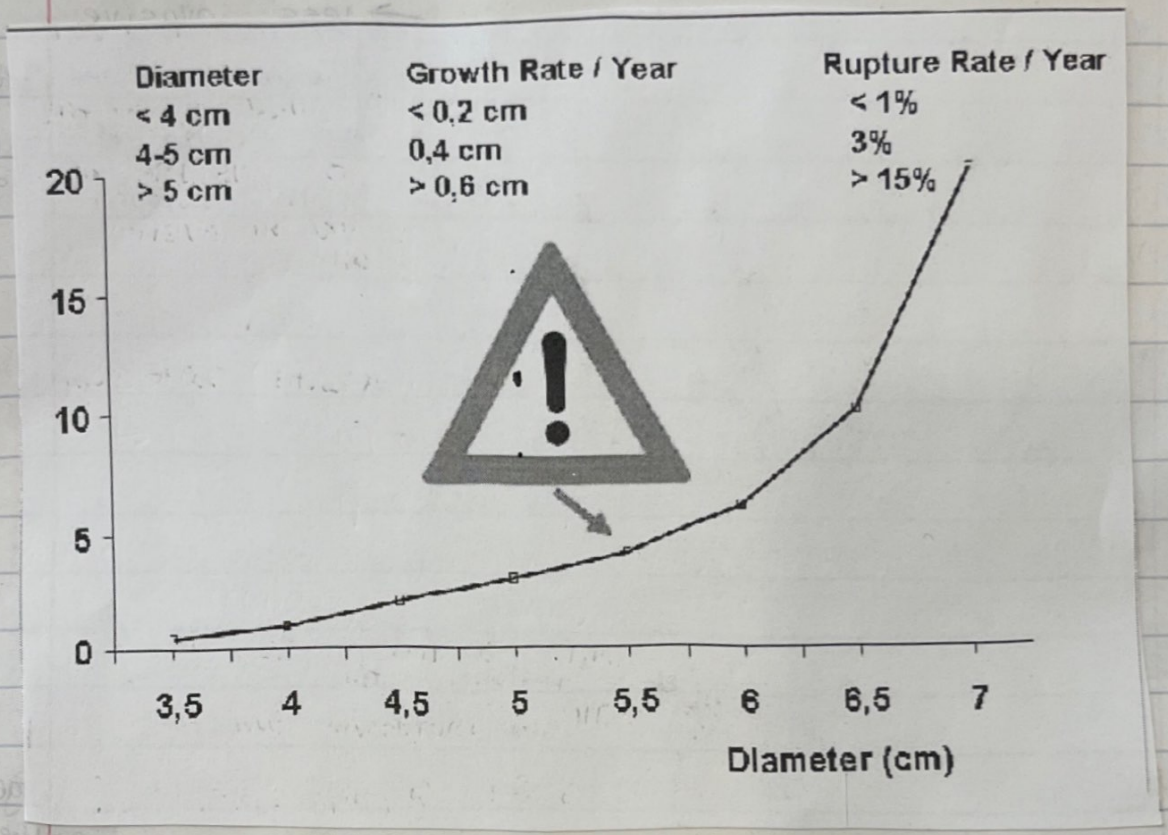
→ less invasive
→ use of endograft / stent graft
→ done through a small incision for catheder in the groin area



→ large incision in the abdomen for clear view of aneurysm
→ repaired with graft.

January 14th 2024

things done today:
- Lit. review
- research in CYSF platform
- started reviewing CFD experiments with aneurysms

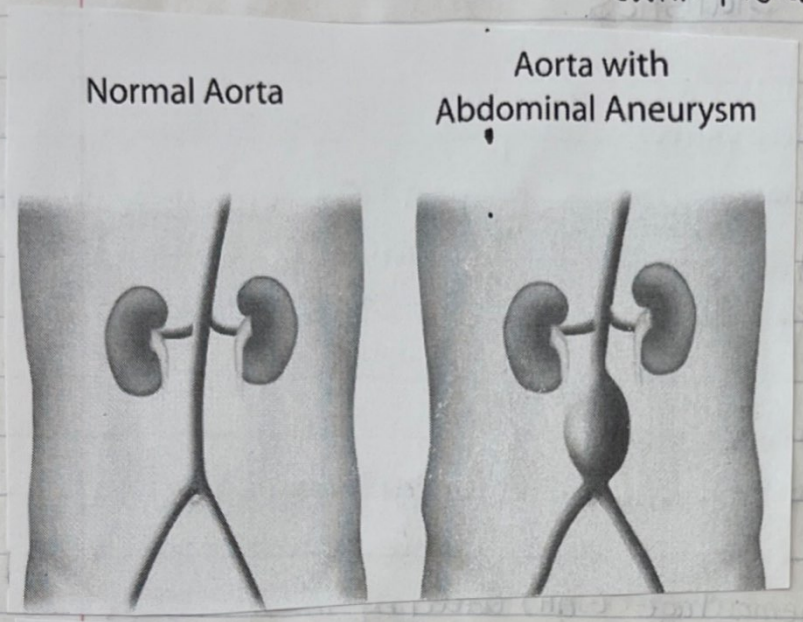


↳ Rupture rate based on the diameter of an AAA

Based on this chart along with various studies, it can be noted that the rupture risk/rate significantly increases after the diameter has reached 5.5 cm or greater. According to population-based samples, the five-year overall rupture rate of incidentally diagnosed aneurysms is 25%-40% in aneurysms larger than 5cm, whereas for smaller aneurysms, 4cm-5cm, that rate is 1%-7%.

January 15th

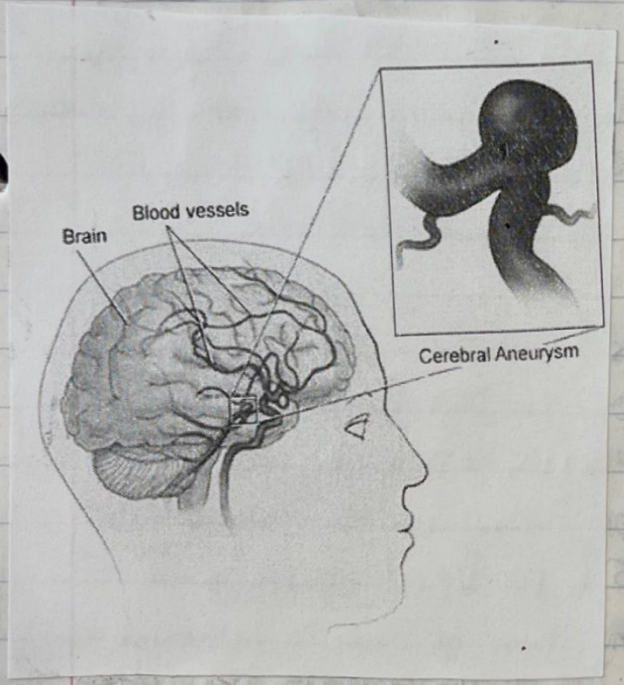
More on types (With Pictures)



Abdominal Aortic Aneurysm

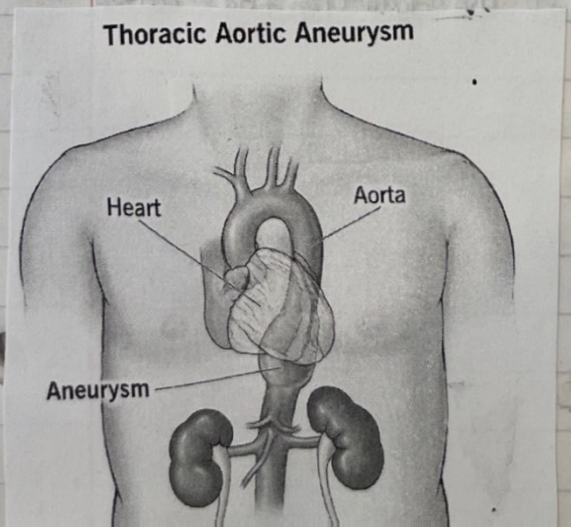
→ located in the lower part of the aorta (infrarenal)

- mostly fusiform (92.2% of all)
- occur in up to 9% of adults older than 65.
-



Intracranial Aneurysm

- most commonly located in the circle of Willis in the bottom part of the brain
- Mostly saccular
- World wide occurence ≈ 3.2%
- mortality rate ≈ 50%



Thoracic Aortic Aneurysm

- occurs in the wall of the aorta within the chest.
  ↳ difference between AAA and TAA
- less common than the AAA and CA
- rarely shows symptoms (95% of cases have shown to be asymptomatic)

January 16th, 2024

Statistics

Abdominal Aortic Aneurysms

↳ Occurence of rupture ranges between 5.6 and 17.5/100,000 individuals per year. The overall mortality rate of ruptured incidences is 80% - 90%.

Cerebral aneurysms

↳ The world wide occurence of cerebral aneurysms is approximately 3.2%. 5% of all strokes are caused by subarachnoid hemorrhage (SAH) (bleeding in the space surrounding the brain), and 85% of these SAHs occur as a result of aneurysmal ruptures. According to studies, it was observed that 50% - 80% of CAs do not rupture throughout an individual's lifetime

Thoracic Aortic Aneurysms

↳ overall, approximately 60% of TAA cases occur in the aortic root, and ascending aorta, 40% in the descending aorta and 10% in each arch or thoracoabdominal segment. The occurence of TAAs is 5-10 per 100,000 individuals per year. and are the 15th leading cause of death in individuals aged anywhere above 55 years and the 19th leading cause for individuals overall

January 17th, 2024

Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics (CFD) is a science that uses digital computer software, numerical analysis, and data structures in order to analyze and solve various problems relating to fluid flow. Various properties are analyzed using this sofware including: pressure, density, viscosity, physical solution, velocity, and temperature. In order to reach an accurate result, these factors are calculated concurrently.

FLUID PROPERTIES/ CLASSIFICATION

Density → amount of mass per unit volume of a substance

Viscosity → resistance of a fluid (liquid or gas) to a change in shape or movement of neighboring portions relative to one another
↳ opposition to flow

Temperature

Pressure → force applied by the fluid per unit area

Specific volume → the ratio of the volume of the material to its mass. Specific volume is the reciprocal of the density of the material

specific weight → amount of weight per unit volume of a substance.

Specific gravity → ratio between density of a fluid and the density of some substance at a specific temperature. (relative density)

Types:

- Newtonian Fluid → fluids that have constant viscosity regardless of the quantity of shear applied at a constant temperature. A linear relationship exists between shear stress and viscosity with these fluids

January 17th, 2024

- Non-Newtonian Fluids → experience an increase or decrease, depending on the fluid, in viscosity when shear is applied.
  example → oobleck, glue, asphalt...
  ↳ can be described in one of four ways regarding behavior
  1. Dilatant - an increase in viscosity when shear is applied
  2. Pseudoplastic - a decrease in viscosity when shear is applied
  3. Rheopectic - an increase in viscosity when shear is applied
     ↳ time-dependent
  4. Thixotropic - a decrease in viscosity when shear is applied
     ↳ time-dependent

Compressible Fluid → a type of fluid that can change its volume under varying pressure. (for example air)

Incompressible Fluid → a type of fluid that cannot change its volume under varying pressure. (water, for example)

January 20th, 2024

COLOUR IN VISUALIZATION FOR CFD

- Color is used in CFD simulations in two key ways. Firstly, it is used to visualize the geometry and allow engineers to be confident that the model constructed is a good representation of the engineering situation. After an analysis has been completed, color is used in post-processed data from the simulations in order to illustrate the complex fluid mechanic phenomena under investigation.
  - ↳ Complex geometry may be involved in a typical CFD simulation that is represented by millions of grid/mesh points. Visualization of this geometry allows the engineer to check that the model is a reasonable representation of the engineering situation and check for any errors that may have been introduced in the process of generating the geometries

BLUE - lower velocity magnitude
Red — higher velocity magnitude
} used to determine velocity magnitudes with a model (flow).

January 21st 2024

(from lit. review)

Vocab.

Wall shear stress (WSS)
↳ the force per unit area that a fluid exerts on a wall parallel to the flow direction

Shear
↳ a strain in the structure of a substance produced by pressure, when its layers are laterally shifted in relation ~~the~~ to eachother.

laterally
↳at, toward or from the side or sides
↔

Shear rate
↳ the rate of change in velocity at which one layer of fluid passes over an adjacent layer.

Fluid Flow
↳ the motion of a fluid that is subjected to different unbalanced forces. →dynamics of the fluid.

Turbulant Flow
↳ type of fluid flow in which the fluid undergoes irregular fluctuations, or mixing, in contrast to laminar flow in which the fluid moves in smooth paths or layers.

Reynolds number
↳ In fluid dynamics, the Reynolds number is a dimensionless quantity that helps predict fluid flow patterns in different situations by measuring the ratio of inertial forces to viscous forces

January 25th, 2024

CFD and aneurysms

↳ how it can be used

- Computational Fluid Dynamics is a technology method that has been studied for a while now in hopes of obtaining a beneficia method of aneurysm evaluation. Models of this technology have been used with two main objectives, one being to identify factors regarding hemodynamics which can be used to tell apart between low and high risk aneurysms in order to develop a system for aneurysm evaluation. The second main objective is to comprehend the effects of different procedures and devices in hopes of improving device designs as well as select a method most appropriate for a patient with an aneurysm.

- With the use of this technology, scientists have been able to identify various variables tying to the characteristics of flow in aneurysms and therefore have been able to come up with several morphologic and hemodyncamic parameters that have proved to have shown potential rupture risk factors. These discovered factors include; Wall shear stress (WSS), maximum wall shear stress (MWSS), Oscillatory shear index (OSI), flow, structure, pressure, the aspect ratio (AR) (ratio between the maximum perpendicular height and the average neck diameter), and the size ratio(SR)(the maximum aneurysm height divided by the average vessel diameter).

January 26th, 2024

Shear Stress and Aneurysms

- Both high and low WSS are implicated in aneurysmal growth, and aneurysm wall tissue may encounter both high and low WSS, however only a minority of aneurysms rupture.
- Factors inherent to the vessel wall's reaction to the changing stresses placed upon it must influence the risk of rupture

NORMAL AND ANEURYSMAL VASCULAR STRUCTURE

↳ There are 3 layers within the vessel wall: the intima, the media, and the adventitia. The innermost layer, the intima, is composed of a single layer of endothelial cells (ECs) on the luminal side of the vessel and is in direct contact with blood flow. The media contains concentric sheets of smooth-muscle cells (SMCs) and collagen. The aneurysm wall structure demonstrates changes in the histology of the vessel wall: a loss of IEL, thinning of the tunica media, and degeneration of the ECM

IEL
↳ internal elastic lamina; membrane of elastic fibres that seperates the intima from the media

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Wall shear stress, the frictional force of blood flow tangential to an artery lumen, has been demonstrated in multiple studies to influence aneurysm formation and risk of rupture.

January 27th, 2024

Hemodynamics

- In medical context, hemodynamics is often referred to as the basic measure of cardiovascular function which includes the cardiac output and arterial pressure. This term also can be referred to as the physical study of flowing blood, including all the solid structures through which it flows (such as arteries).. There cannot be a true understanding of circulation within the body without a basic comprehension of basic hemodynamic principles.
  - ↳ Basic variables used in hemodynamics include: flow, volume, pressure, compliance, velocity, and resistance.

[BLOOD]

- Blood is essentially a Non-newtonian fluid which means that it is a fluid with a Shear rate-dependent viscosity. In other words, as shear rate increases, the viscosity decreases in blood.
- The viscosity of blood comes from the shear rate-shear stress connection. When fluids have a higher viscosity, they experience less deformation and have slower flow in comparison to fluids with a lower viscosity.
- Blood demonstrates a behavior known as shear-thinning meaning that a non-linear decrease is present in the viscosity while there is an increasing shear rate.

- The diameter of blood vessels can decrease from 1000 μm down to 3μm and therefore the blood's viscosity decreases down to about a 10μm diameter before increasing sharply from the diameters of vessels goin from 10μm down to 3μm. Overall, the flow of blood in smaller vessels is significantly complex.

January 28th, 2024

Things done today: - continued a more thorough literature review on how CFD has been applied to aneurysms (mainly device-based research (coils, stents))
- researched hemodynamics & CFD in general
- worked on the research portion of the OYSF platform
- Found some open source data to choose from.

January 30th 2024

Significant note from article

WSS
↳ wall shear stress

↳ it was suggested in a study that in contrast to the pathogenic effect of a high WSS in the initiating phase, a low WSS may facilitate the growing phase and may trigger the rupture of a cerebral aneurysm by causing degenerative changes in the aneurysm wall. The WSS of the aneurysm region may be of some help for the prediction of rupture

• From "Shear stress and aneurysms: a review"

Febuary 1st, 2024

CFD Application to Aneurysms

- To investigate the effect on aneurysms, particularly intracranial aneurysms, CFD has proved to be a potential leading research tool for determining and investigating the effect of fluid dynamics within intracranial aneurysms and any attainable geometry.

- The maiority of CFD studies have mainly focused on the analysis of blood flow characteristics and the effect they have on the aneurysm wall dynamics
  - ↳ these studies have shown that it is effective to have a comprehension on the effects of different blood viscosity models on intraneurysmal hemodynamics. This is important regarding the comprehension of the progression of intracranial aneurysms.

- Aneurysm rupture occurs when the tissue stress exceeds the tissue strength. It would be effective if the stress and strength distributions in an aneurysm wall could be accurately determined

[CHALLENGES WITH THIS METHOD]

- only information that can be reliably obtained from clinical imaging is the geometry of the aneurysm. It is not possible to obtain information on tissue composition, thickness, and structure that is required for an accurate structure analysis.
  - ↳ However, CFD does offer a method to use the geometric data obtained from clinical imaging to assess a single aspect of the biomechanical state of an aneurysm.

- CFD provides a tool for exploring hypotheses and potentially reducing the number of variables and enabling the ranking

February 2nd, 2024

Coiling method on aneurysms and CFD →

- Health care providers use endovascular coiling, a form of endovascular embolization, to block blood flow into an aneurysm. An aneurysm is a weakened area in the wall of an artery, therefore if an aneurysm ruptures, it can cause lifethreatening bleeding and brain damage (intracranial). Therefore, preventing blood flow into the aneurysm helps to keep it from rupturing

PROCEDURE:

- Small metal coils are inserted into the aneurysm through the arteries that run from the groin to the brain. The coils remain in the aneurysm; they are not removed. They stop blood flowing into the aneurysm and therefore reduce the risk of a bleed / rebleed.

CFD & coils

- In a clinical setting, various devices, including embolic coils have been evaluated with the use of CFD analysis. The blood flow changes were studied before device application as well as after in treated aneurysms. In a study, the effect of coil embolization in ruptured cerebral aneurysms were investigated using CFD. The hemodynamic parameters, including blood velocity, pressure distribution on the vessel wall, and blood flow patterns were investigated. the scientists in the study used an accurate 3-D model representation from a clinical case to perform the study/research. The hemodynamic changes were observed during the different stages of coiling processes. As a result, it was observed that the first coil influenced notable effects on blood flow patterns despite the coil only occupying cont →

February 2nd, 2024

Coiling/CFD continued →

→ 3.6% of the medium. It was also noted that gradual relief of wall pressure occured at the aneurym dome with a stepwise introduction of coils

Overall, CFD can and has been used in the hopes of obtaining information regarding the effectiveness of various tools/medical devices on aneurysms.

February 3rd, 2024

Fusion 360 (Autodesk Fusion)

What is it? (directly from autodesk.com)

Autodesk Fusion combines CAD, CAM, CAE, and PCB into a single, integrated cloud software platform. It includes all the tools that you need to go from design to manufacturing, seamlessly.

What can you do?

- Explore design iterations with easy-to-use 3D modeling tools.
- Produce high-quality CNC machined parts with integrated CAD/CAM
- Gain access to unified electronics design
- Test the performance of your designs with 3D simulation tools
- Explore manufacturing-ready outcomes with generative design
- Collaborate and manage your data seamlessly in the cloud.

FEATURES

- 3D design and modeling
  - ↳ 3D design tools that include sketching, direct, surface, parametric, mesh, and free-form modeling, sheet metal.

- Manufacturing
- Electronics
  - ↳ tools (PCB design tools)
- Simulation
  - ↳ Gain access to static and thermal stress, modal frequency, buckling, event simulation, shape optimization, and more.
- Generative design
- Collaberation and data management.

February 5th - 7th 2024

Things done:
- installed Fusion 360 by creating an educational account on Autodesk.
- Worked on CYSF platform, continued thorough research and case studies
- literature review
- Watched tutorials and read about different features on Fusion 360 and figured out how to use them

February 8th, 2024

Things done today:
- CYSF platform
- Fluid dynamics studying/running Fusion 360

Velocity - Contour method → a method of measuring stream discharge in which point velocity measurements are translated in average cross-sectional flow velocities by contouring the point velocities; these averages are then multiplied by the areas of the cross sections to give the discharge

↳ discharge → The volumetric rate of flow or volume flux

flux → the rate of flow of some quantity often used in reference to the flow of some form of energy.

* CFD invention: ↳ In the early 1990s, London, Brian Keelan and Jon Wood were generally given the credit for the market-changing invention of CFD.

February 9th, 2024

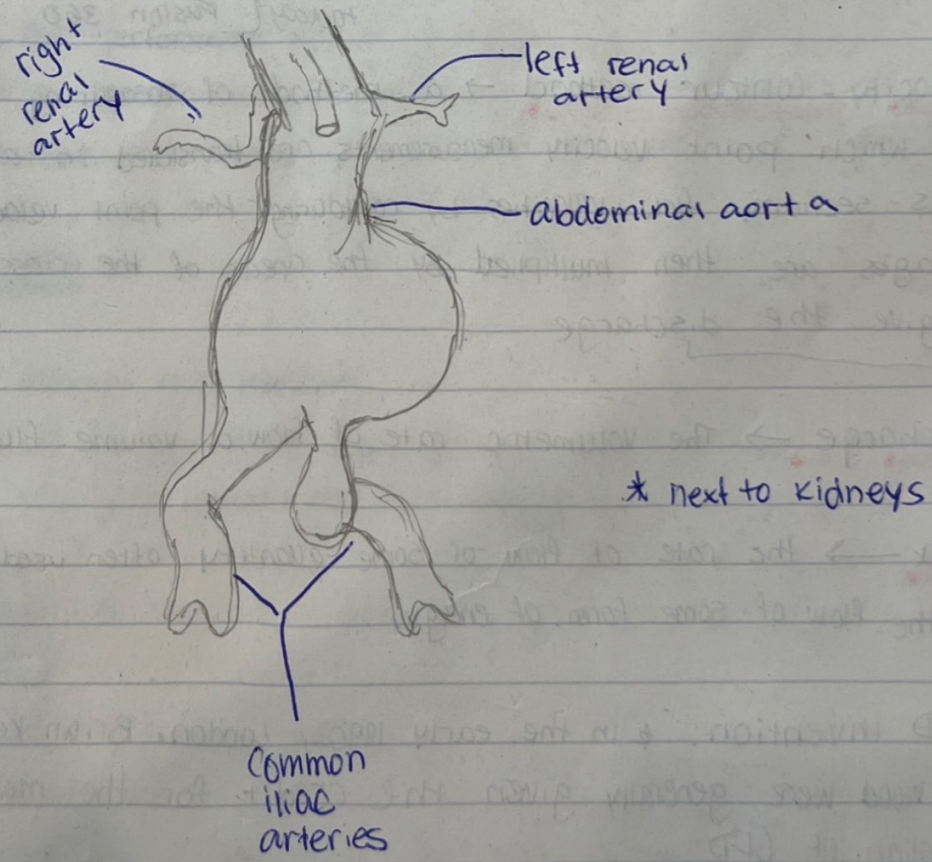
* Run first round of calculations tomorrow

Data (in depth)

- Open source site → printables.com
  - ↳ segmentation of an abdominal aortic aneurysm obtained from a CT scan.

- Model appears to be from the infrarenal area of the abdomen because of the 2 thicker vessels branching out below the aneurysm and the 3 thinner ones above

ROUGH SKETCH OF MODEL



* next to kidneys

February 10th, 2024

Problem planning/structuring
(CYSF Platform)

Abdominal Aortic Aneurysms are the cause of over 175,000 deaths worldwide. ~~The~~ symptoms of AAAs are relatively rare, most of them only ~~showing~~ occuring when the aneurysm has ruptured, causing a fatal bleed, the mortality rate of rupture reaching 80% - 90%.

Abdominal Aortic Aneurysms (AAAs) are the cause of over 175,000 deaths worldwide annually. In comparison to statistics in 1990, it has been noted that an overall increase of 82.1% occured in ~~globally observed~~ deaths globally over the years. Furthermore, these aneurysms rarely show symptoms, most only occuring when rupture has occured. The overall mortality rate of AAA rupture reaches 80%-90% due to the fatal bleed that occurs after rupture. ~~CAD~~ Computational Fluid Dynamics (CFD) has shown ~~to be~~ potential regarding risk-assessment of rupture within aneurysms. This technology has been used in studies, in order to study the hemodynamic parameters within aneurysms. When the tissue of the vessel wall exceeds its overall strength, a rupture occurs. Therefore, by using CFD to determine strength and stress distributions within aneurysms, with accuracy, a technology/method can be developed regarding risk of rupture assessment in aneurysms.

- Hard to notice due to them being asymptomatic
- mortality rates growing
- high fatality rate after rupture

February 11th-15th 2024

METHOD PLANNING

Step 1) Geometry-preparing

↳ Transform mesh body into solid body

- Selected "MESH" and went into "MODIFY" → "convert Mesh"
- Solid body was generated

↳ Preperation of Flat surfaces for setting boundary conditions later

- By using a cutting plane, the top piece of the aorta as well as the tips of the common iliac arteries were cut, creating flat surfaces
- "Split body" feature is used

↳ Exportation of the component geometry.

↳ prepared geometry was imported to Autodesk CFD as a .Step file.

(step 2) AUTODESK CFD

① First, the blood properties are assigned to a fluid volume out of the CFD fluids library

② Set up of boundary conditions → The velocity of blood travelling down the aorta is approx. 150-175 cm/sec, so 175 cm/sec was set as the velocity magnitude entering from the top of the aorta, down. On the other end of the aneurysm model, unknown boundary conditions were set

Before CFD analysis is run:

- The geometry is broken down into smaller pieces called elements Each element has a corner which is called a node. At the nodes, the calculations are performed.
- The mesh is made up of these elements and nodes.
- Most elements in 3-D models have a tetrahedral shape whereas in 2-D models most elements are triangles.

Unknown Boundary Conditions (from Autodesk CFD documentation)

↳ "This is a "natural" condition, meaning that the boundary is open, but no constraints are applied!"

Method planning continued

Mesh

February 16th, 2024

Automatic Mesh Sizing

↳ defines a mesh that is optimized for the model and accurately represents every detail of the geometry. For further refinement, Mesh Adaptation was used.

↳ uses solution results to progressively improve mesh definition.

- The simulation was run several times. Each time, the results in the previous cycle are used to improve the next cycle. The result is a mesh that is optimized for the particular simulation
  ↳ the mesh is finer for high gradient regions, and coarser elsewhere. (From Auto Desk CFD documentation)
- 2 adaptive cycles were run and the mesh was refined from approximately 1M to approx. 3.7M fluid elements.

- Solver was set to calculate steady-state solution, and the results were saved every 100 iterations. Low Re k-epsilon model was used to model turbulence, and heat transfer was not considered

→ *put into Method section of CYSF platform.*

February 18th - 21st, 2024

- Focused on (finall) observations and started documenting results (conclusion possibilities)
- Practiced running the model through Autodesk CFD consistently

Results of calculations: (3 observations)

- The blood flow structure within the AAA was definately interesting. The aneurysm expansion blood flow generates a strong low velocity vortex zone which partially redirects the blood to one of the iliac arteries while the rest of the flow, the dominant flow, goes around this zone and accelerates significantly in the other iliac artery which creates a significantly faster flow.
  - ↳ After some researeh I found that a similar result was acheived in an article by Liu, D et al. → "Comparison of small symptomatic and asymptomatic abdominal aortic aneurysms based on computational Fluid Dynamics analysis." in another study by Yue Qui et al. → "Association Between Blood Flow Pattern and Rupture Risk of AAA based on CFD.", it was said that this flow pattern occurs in 32.1% of AAA cases.

- In a study by Boyd AJ et al. → "Low WSS predominates at sites of abdominal aortic aneurysms rupture" → This flow pattern was associated with the intraluminal thrombus (ILT) deposition. The ILT is a blood clot, which consists of blood cells, blood proteins, platelets, and cellular debris and forms between the aorta wall and circulating blood.
  - ↳ present in 74% of AAAs.

- Low velocity blood recirculation increases the possibility of the ILT forming.

February 22nd, 2024

Observations, Continued.

After a comprehensive literature review, it can be noted that WSS is an important hemodynamic parameter; WSS correlates with blood flow dynamics clearly in the AAA CFD model. The first region observed with an elevated WSS is most likely associated with the blood flow impinging the artery's wall. An elevated WSS can also be seen along the dominant flow and low WSS zone in the region of slow recirculation.

wall shear stress

↳ Low WSS might be a more accurate parameter than a maximum diameter in terms of predicting the rupture of AAAs.

*put onto platform

More observations:

- Static pressure was plotted to observe the elevated pressure regions. It was interesting to see that there were 2 slightly elevated pressure regions, the first one being in the zone of the impinging region and the second being in the zone where the flow is hitting the wall of the aneurysm at the bottom. An elevated pressure was also noticed slightly between the two regions.
  - ↳ most likely related to the blood flow pushing up against the wall of the aneurysm.
  - The push could possibly explain what/why the effect of impingment affects aneurysm growth because it is stretching it by pushing against the wall.

February 24th, 2024

Issues/Possible sources of error

[ISSUE]

↳ Autodesk CFD does not really run well on windows 10 as it is not a mainstream software. Out of approximately 5-6 runs, I only had 1 successful outcome. Additionally, my computer would often freeze and lag during the runs, and Autodesk CFD was shutting down which caused different errors to be outputted. Each successful run was around 24 hours.

- Autodesk CFD can't export data properly for post-processing, so all post-processing had to be done inside or in the Autodesk CFD viewer which is rather primitive. Exporting options don't really work properly

[SOURCES OF ERRORS]

(1) Mesh independence → the finer the mesh, the more accurately the flow pattern and different physical effects can be captured

↳ I couldn't run further mesh refinement after the 3.6M elements because Autodesk CFD was freezing.

- Ideally, manual refinement is needed, but I don't have enough experience and knowledge to run such advanced meshing operations.

(2) Convergence

↳ CFD simulations start with an initial guess for the solution and then gradually refines it through multiple iterations. I used some default criteria for convergence which looks quite loose since the choice was made in favor of the speed of calculations

(3) Non-Newtonian effects of blood were not considered

February 25th – March 5th, 2024

- Touching up the CYSF platform and finishing up.
- starting to plan presentation → slide show

Slides (10 minutes)

Title: Blood Flow Study Within Abdominal Aortic Aneurysms

1. what are aneurysms?
2. Problem
3. Data, 3D model
4. CFD model
5. Results
6. CFD blood flow simulation video
7. Future work
8. citations

* start thinking about what to say in what structure