JÓVENES EN LA CIENCIA
REVISTA DE DIVULGACIÓN CIENTÍFICA

SENSITIVITY MESH ANALYSIS OF BLOOD FLOW FOR STUDY HYPERELASTIC AORTA MODELS

Melendez, Noel Emmanuel (1), Vidal-Lesso A. (2)

1 [Mechanical Engineering, University of Guanajuato] | [n.mahungmelendez@ugto.mx]

2 [Department of Mechanical Engineering, Engineering Division Campus Irapuato – Salamanca, University of Guanajuato] | [agustin.vidal@ugto.mx]

Resumen

La Aorta es una de las arterias más grandes del cuerpo que se extiende sobre el corazón. Se extiende sobre un pie de largo aproximadamente con un diámetro aproximado de 25 mm. Aparte de ser la arteria más grande, es la parte que mas trabaja en el corazón debido a su trabajo para transportar la sangre oxigenada desde el corazón al cuerpo. El estudio del flujo sanguíneo en la aorta se realiza por muchas razones, pero una de las principales razones es determinar si se produce algún daño sanguíneo en la aorta. Para analizar el flujo de sangre se necesitó la ayuda de un software de volumen finito. La simulación de dinámica de fluidos (CFD) ayuda a determinar las características del flujo sanguíneo en toda la aorta, pero para asegurar que los resultados sean óptimo y adecuados, se realizó un análisis de sensibilidad de malla. Este análisis se realiza para optimizar el tiempo computacional y asegurar que el resultado dado sea adecuado. Los resultados del estudio se sitúan sobre los parámetros de simulación y por lo tanto son útiles para determinar las características del flujo sanguíneo a través de la aorta.

Abstract

The Aorta is one of the largest artery in the body it extends over the heart. It extends over a foot long approximately with an approximate diameter of 25 mm. Apart of being the largest artery, it is the hardest working part of the heart because of it job to transport oxygenated blood from the heart to the body. The blood flow study in the aorta is done for many reasons but one of the main reasons is to determine if any blood damage occurs in the aorta. To analyze the blood flow the help of a volume finite software was needed. The Computer Fluid Dynamics (CFD) simulation assist to determine the blood flow characteristics throughout the aorta but to ensure that the optimal and adequate a sensitivity mesh analysis was done. This analysis is done so has too optimize the computational time and to ensure that the result given is an adequate one. The result of the study is placed on the simulation parameters and so has too determine the characteristics of the blood flow throughout the aorta.

Key Words Aorta; Mesh Sensitivity; Finite volume; CFD; Blood flow

INTRODUCTION

The analysis of the human body and it systems has been an issue that by the advancement of technology we have been able to understand it more. With the technology in this day and era we have been able to recreate limbs and let them move has it they were natural. But they are some things that have not changed since the 19th century. One of those elements is the characterization and the analysis of the cardiovascular system. They are records that prove that in the 20th century they are some methods used in the 19th century. The method of trial and error is one of them. Researchers still use this method in *In vivo* and *In vitro* experiments.[1] But with the exponential advancement of technology some of those methods have lessen. The advancements of technology like the magnetic resonance imaging (MRI), Computerized Tomography (CT) scans and computer processing has made it possible for the Lessing of trial and error iteration that need to me made for a successful experiment.[2]

The Autonomy of the Aorta

The cardiovascular system starts at the aorta when the left ventricle pumps blood in to it. It is a tubular structure which is of about a foot long and over an inch in diameter. The Aorta is divided into four parts, the ascending aorta which ascends from the top of the heart and is usually 2 inches long. The coronary arteries branch off from this apart of the aorta. The ascending aorta bends downwards to join the aortic arc which curves over the heart and gives rise to branches that take blood to the head, neck and arms. [3]The descending thoracic aorta travel down the chest and branches off to supply blood to the ribs and chest structure. The abdominal aorta starts from the diaphragm and runs down to split in two iliac arteries that supply the pelvis and legs with blood.

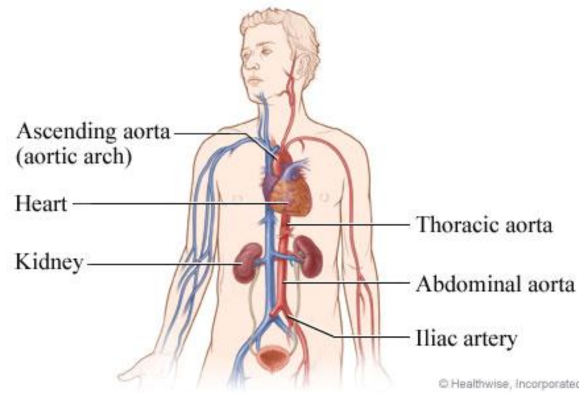


IMAGE 1: A photographic representation of the aorta

Meshing

Meshing is considered has the generating of geometric subdomains like hexahedra or tetrahedra when solving in 3-dimencions and in quadrilaterals and triangles in 2-dimencions. The governing equation are discretized and them solve in each subsection. [4]This is done usually by one of three methods of approximation of systems of equations: finite volume, finite elements, or finite differences. Also, every type of meshing has their advantages and disadvantages. Usually what results determine the type of mesh wants to be obtained, the complexity of the geometry and by the resources you have to calculate the equations.

Hyperelastic material

A hyperelastic material is an elastic material that returns to its original shape after the the forces is removed. But also, it can be classified has a Cauchy-elastic because the stress can be determined by the present state of the deformation and not by the history of the deformation. The difference of a linear elastic material and a hyper elastic material is the stress-strain relationship derives from a strain energy density function or in other words it is not factored by a constant, (see fig 3). The term Hyperelastic is usually referred to describe biological materials.[5] The term for used for non-biological materials is Elastomers

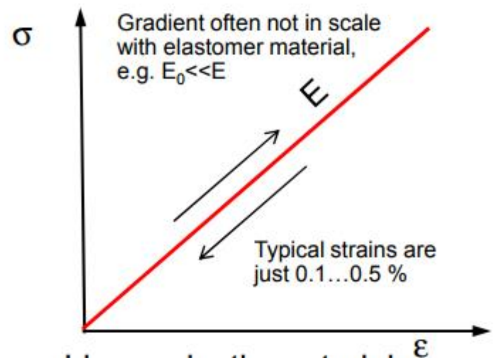


IMAGE 2: Linear Elastic Material Graph

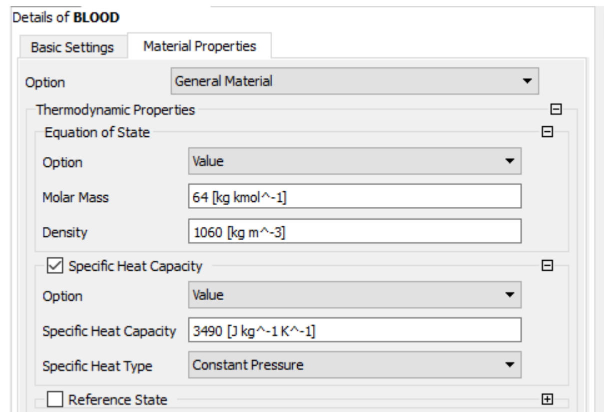


IMAGE 4: Fluid Properties

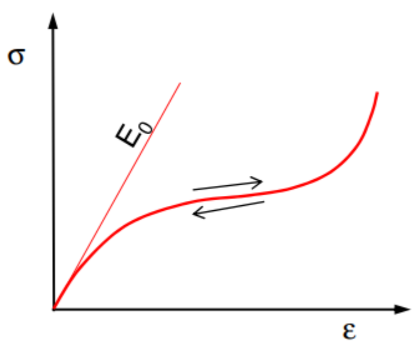


IMAGE 3: Hyperelastic Material Behavior

SIZE (MM)	TYPE	NUMBER OF ELEMENTS	NUMBER OF NODES
5	Tetrahedrons	126842	37836
2	Tetrahedrons	142865	41594
1	Tetrahedrons	496564	121306
0.9	Tetrahedrons	653362	154387
0.8	Tetrahedrons	901171	205292
0.7	Tetrahedrons	1318107	288862
0.6	Tetrahedrons	2067985	435464
0.5	Tetrahedrons	3588616	730236

TABLE 1 : Size of elements

MATERIAL Y METHOD

The Materials used to study the blood Flow of the aorta was a computer capable enough to run the simulation. The CFD software CFX from ANSYS was used to accomplish the study. The meshing was done with the meshing software of ANSYS. Also, a rectified model of an aorta was obtained from previous studies

The methodology that was used to make the analysis was one of investigation and iteration.[6] A thorough investigation in cardiovascular book and scholarly journal was done, to find a case study adequate for the study. The aorta model was loaded to the CFD platform and meshed in the following sizes shown on the table. The properties were taken from a previous study.[1]

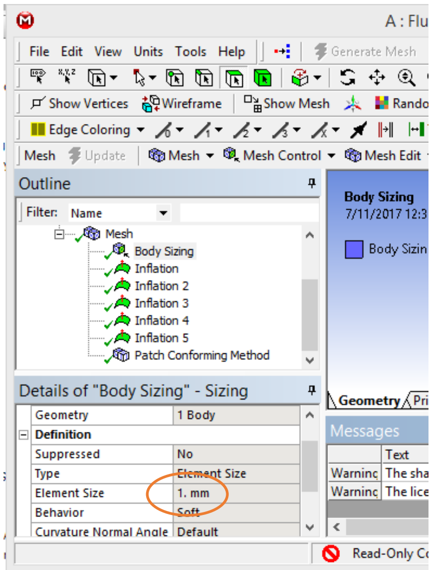


IMAGE 5: Location of size modification

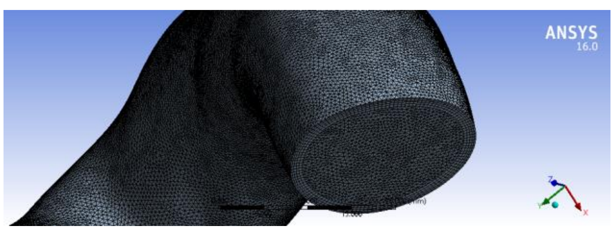


IMAGE 6: Meshing of aorta

The boundary condition was applied to the model has listed on the table:

INLET	1.4 m/s
OUTLET 1	120 mmHg
OUTLET 2	120 mmHg
OUTLET 3	120 mmHg
OUTLET 4	120 mmHg

TABLE 2 : Boundary Conditions

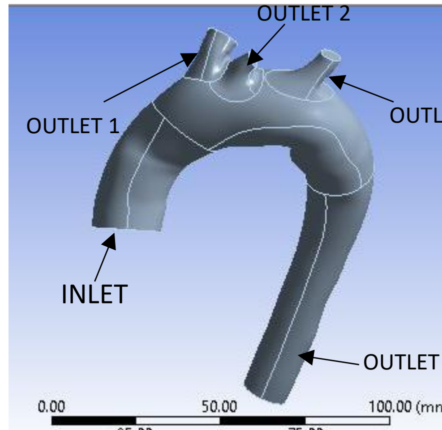


IMAGE 7 : Boundary Conditions

RESULTS Y DISCUSSION

The simulation was done and the results were generated. The results were generated has as shown and the numeric results of the pressure, wall shear and the velocity at the exit were taken.

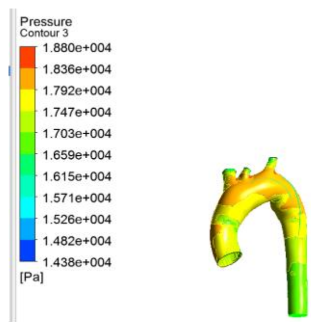


IMAGE 8: Representation of the difference in pressure

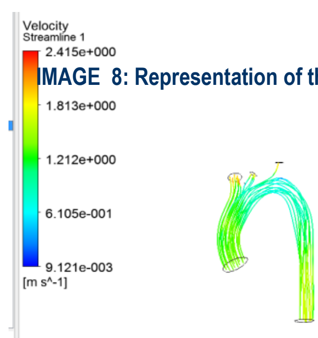


IMAGE 9: Representation of the difference in velocity

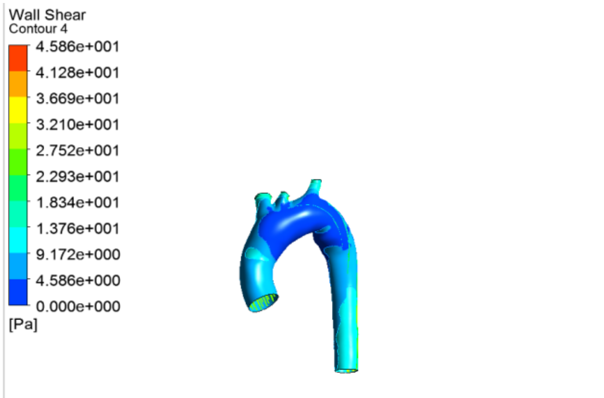
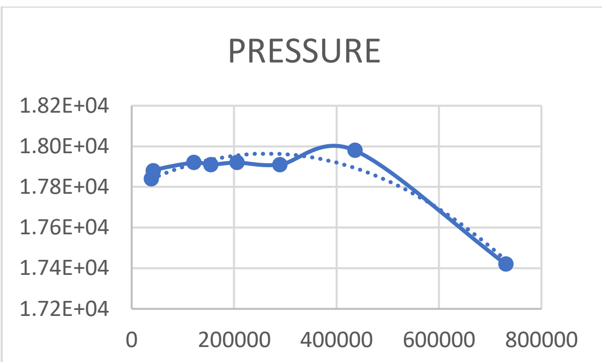
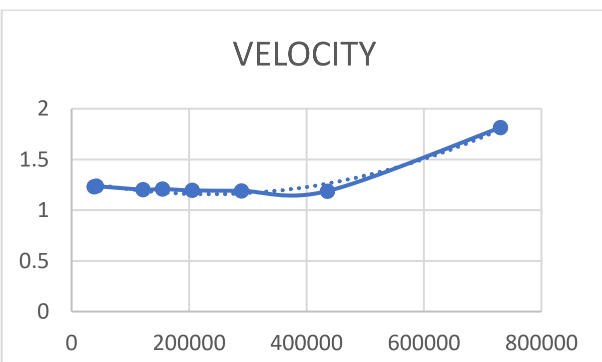


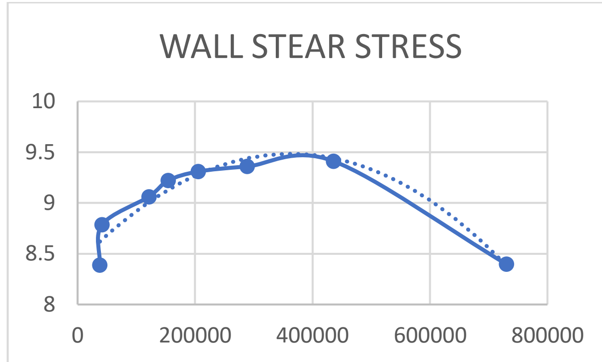
IMAGE 10: Representation of the difference in wall shear



GRAPH 1 : MESH SENSITIVITY ON PRESSURE



GRAPH 2 : MESH SENSITIVITY ON VELOCITY



GRAPH 3 : MESH SENSITIVITY ON WALL SHEAR

CONCLUSION

The pressure, velocity and wall shear at the exit were placed in a graph. The pressure as seen in graph 1 remains constant until the last mesh size of 0.5 mm. The graphs 2 and 3 show the velocity and the wall shear of the exit as it shows the value remains constant until the end this is because of the concentration of the mesh and the results become more precise. As shown the last mesh size is more accurate but the computing time is too much. In conclusion with the approximation of the graphs it can be said that the optimal size of mesh is 0.8mm with 901171 elements. This size is the optimal because in all the analysis approximation is gives us an adequate result. But also with the size of 0.8mm the computational time was of 2 hours 15minutes 89 seconds which was the minimal time.

ACCREDITATION

The authors give credit to the University of Guanajuato in giving them the opportunity of presenting the project. Also gives credit to Dr. Agustin Vidal in accepting to be the assessor of the project.

REFERENCES

[1] Richard Brian Medvitz, "development and validation of a computational fluid dynamic methodology for pulsatile blood pump design and prediction of thrombus potential," no. May, 2008.

[2] T. I. Józsa and G. Paál, "Boundary conditions for flow simulations of abdominal aortic aneurysms," Int. J. Heat Fluid Flow, 2014.

[3] P. I. The - Aaronson, Cardiovascular System at a Glance,. 2013.

[4] A. C. Benim, A. Nahavandi, A. Assmann, D. Schubert, P. Feindt, and S. H. Suh, "Simulation of blood flow in human aorta with emphasis on outlet boundary conditions," Appl. Math. Model., vol. 35, no. 7, pp. 3175–3188, 2011.

[5] M. D. Robert M. Anderson, The Gross Physiology of the Cardiovascular System. 2012.

[6] B. M. Yun, D. B. McElhinney, S. Arjunon, L. Mirabella, C. K. Aidun, and A. P. Yoganathan, "Computational simulations of flow dynamics and blood damage through a bileaflet mechanical heart valve scaled to pediatric size and flow," J. Biomech., 2014.