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Original Article

Hemodynamic in Human Diabetic Abdominal Aneurysmal Aorta Using Computational Fluid Dynamics

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Abstract *- This study is based on image-based CFD (Computational Fluid Dynamic) that will help in providing an enhanced understanding of the blood pressure impact on the wall of Abdominal Aneurysmal Aorta (AAA) for diabetic patients and its relationship with whole blood viscosity (WBV). This relation can provide the physician an indication about the consequences of diabetes disease on the AAA. Simulation technique was used as it is difficult to perform such studies in real patients where AAA problems have no symptoms. Thus, the arterial systems computational models are used to inspect the growth, rupture, and thrombosis of the aneurysm. Idealized 3D AAA models are created to analyse the aorta pressure in different areas. The CFD, is a software that has been used to determine the relationship between WBV and AAA wall pressure and then to compare the obtained values to blood viscosity (BV) for normal subject. The results were compared between the normal and diabetic models. The change in the pressure values is due to the change in the viscosity values. The values of the diabetic patient's whole blood viscosity are higher compared to the normal viscosity, which in turn is recorded as increasing the pressure on AAA wall. The results show that the BV has a direct impact on the AAA wall pressure values. Therefore, the pressure on the AAA wall increases as BV value increases.*

Keywords — *Abdominal aortic aneurysm, computational fluid dynamics, diabetes, rupture*.

I. INTRODUCTION

The AAA is a limited and long-lasting expansion of the abdominal aorta. It is one of the largest arteries in the body which occurs due to the irreversible weakening of the aortic walls. It is founded that AAA causes death when it is rupture from 78-94%, and it affects elder men more than women. Also, it is a disease that has no symptoms and this is a major concern regarding threatening the patient's life. We examined the changes in internal pressure and blood flow when the AAA increases in diameter. Thus, to understand in what way the stress is spread and the factors that affect their distribution is significant in assessing the possibility for rupture. Moreover, using simulation like CFD image techniques provide us with the necessary data to study such cases. The CFD simulation is the most preferable approach to investigate with great convenience, low cost and high speed with permitting prediction in its initial growth stage. Additionally, CFD technique is also utilized to analyse the reverse situation of the arterial deformation. Hemodynamic parameters of any disease reveal appropriate direction for clinical treatment. Thus, numerous studies have used CFD to acquire cardiovascular hemodynamics [1, 2]. A study by Soudah et al. inspected the association for hemodynamic parameters and the rupturing of AAA [3]. The study converted 2D images of unhealthy patients to a 3D geometry using CFD approach which revealed the growth of the AAA rupture is intensely linked with the arterial geometrical and hemodynamic loads.

Pulsating blood flow moves over the cardiovascular structure to transport vital elements hormones, nutrients and oxygen to the organ of the body. Uncommon distortion or thinning of the artery lumen triggers uneasiness to the patient due to lesser material flowing through the body subsequently lack of the blood flow to the organs. Few studies revealed that such diseases associated with diabetes, obesity, stress conditions, family history and smoking [4, 5]. Therefore, diabetes is the main factor for any cardiovascular diseases [6] and also for events associated with occlusive intimal atheroma, such as myocardial infarction, stroke, and lower limb ischaemia [7]. In UK, AAA is rare among diabetic patients and also diabetic patients are half as likely to develop an AAA as those without diabetes [8]. The dynamic viscosity of the blood and aortic walls are effected by diabetes [9].

The blood viscosity is the amount of the stickiness and the thickness of the blood. Also it is a direct amount of the blood volume to move through the vessels of the blood. In addition, measurement of the blood states the amount of the blood friction against the vessels, how tough heart would have to work to pump the blood through the body and lastly how much oxygen is to be transported to the organs and

tissues. Blood dynamic viscosity is higher with diabetes making is difficult to flow in comparisons to healthy blood. Microcirculation also gets disturb with increased blood viscosity. Despite having same theoretical pathogenic mechanisms, the studies present for the association between the AAA and the diabetes is inadequate and conflicting. A study by Cogan. [10], measured serum-viscosity by viscometer using an Ostwald capillary and no change was found in the serum-viscosity between 44 diabetics and 9 non-diabetics patients blood but the whole-blood viscosity was not studied. Moreover, cardiovascular disease is often affected by diabetes and negative relationship with AAA are found. Thus, the aim of the present study is to examine the association among the AAA and the diabetes.

II. METHODOLOGY

A three-dimensional patient-specific module of an AAA is used to see the aorta pressure in different areas. Moreover, we are simulating the aneurysm geometry in three phases; phase 1: normal value to test the validity of the model and its result, phase 2: viscosity value for diabetes and phase 3: test the diabetic values and compare them with the normal one.

Figure 1 depicts the aneurysm geometry used in the simulation. A 3D aorta geometric model with a single inlet for velocity and an outlet for pressure and aneurysm wall as a solid material is reconstructed from each patient's CT images. The 3D reconstructed model was imported to ANSYS v15 software for the computation.

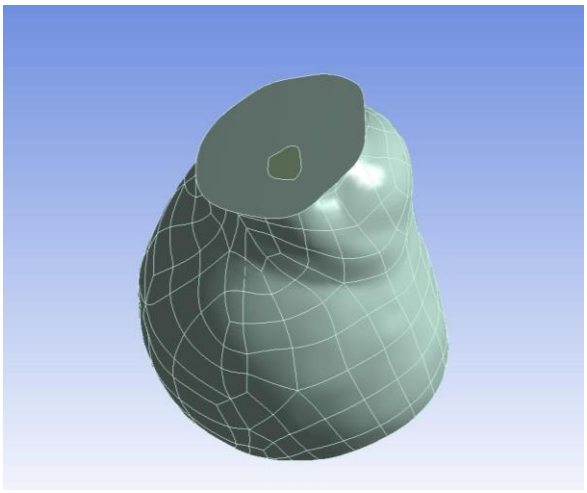
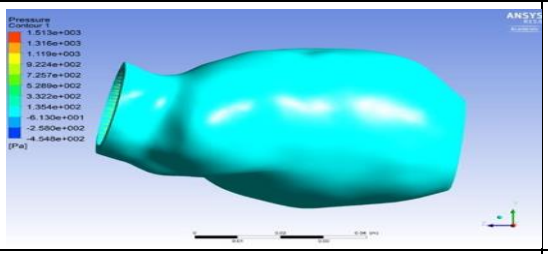
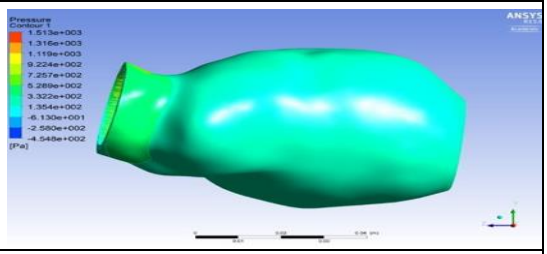
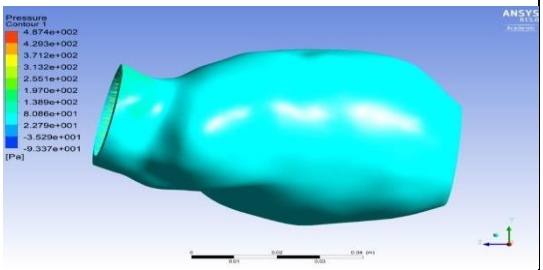
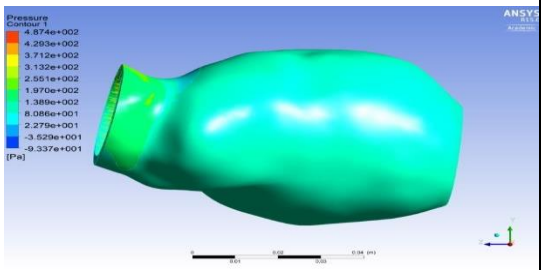


Figure 1: Aneurysm Geometry.

III. RESULTS

The results show that the WBV values of a diabetic patient are higher compared to the viscosity value of a normal patient, which in turn is noted as increasing the pressure on AAA wall.

Figure 2 depicts that normal viscosity value on left side is different from diabetic value on the right side.

Viscosity value kg/m-s (Normal)	Viscosity value kg/m-s (Diabetic)
0.00287 [2]	1 [1]
	
0.00287 [2]	0.27632 [1]
	
0.00287 [2]	0.212 [11]

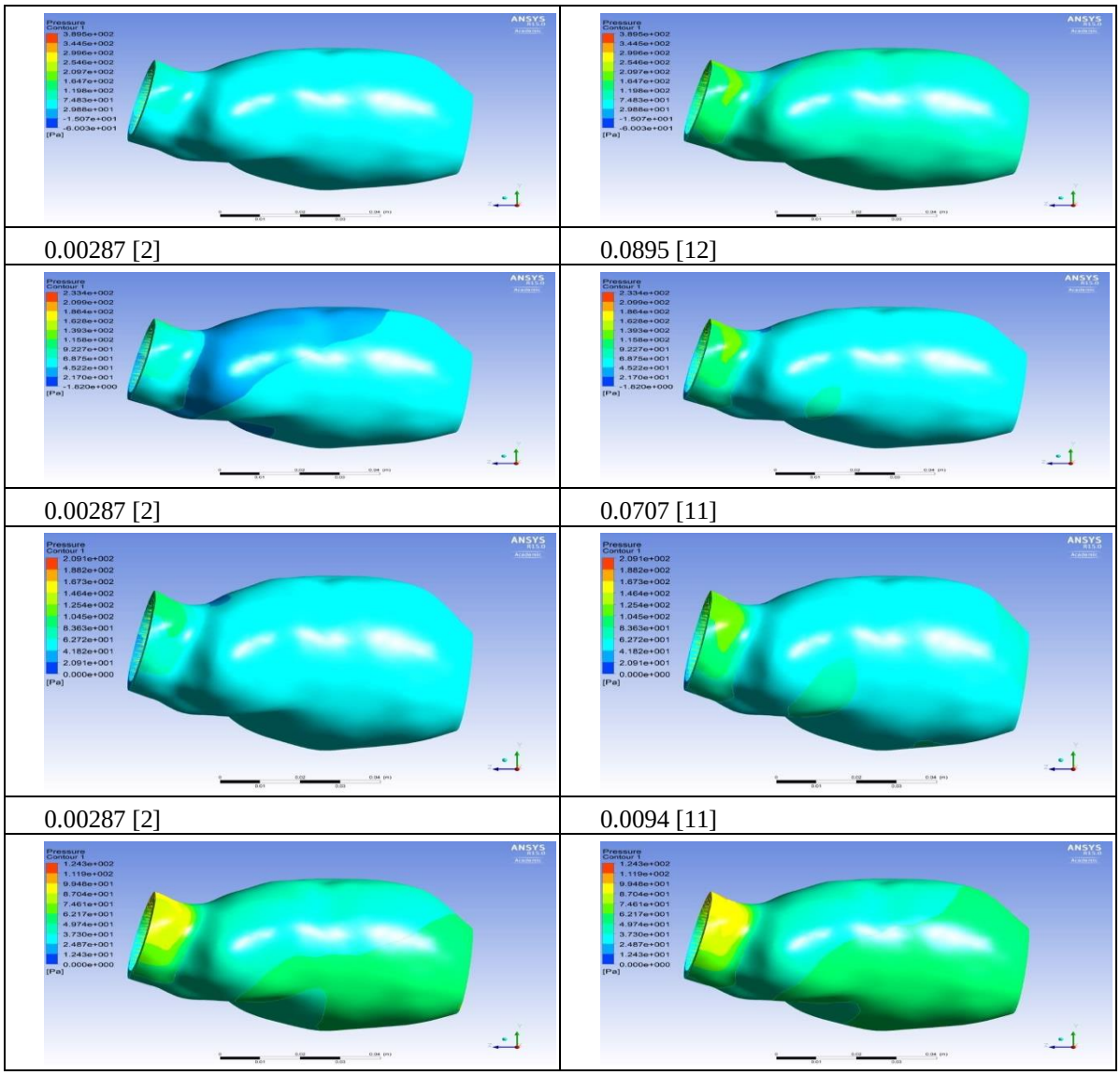


Figure 2: Normal and Diabetic Viscosity Value.

Table 1 illustrates the increase in the AAA wall pressure is more than 400% when the viscosity value is 1 kg/m-s. This proves that there is a direct relationship between the AAA wall pressure and the blood viscosity. Furthermore, the other values of the blood viscosity shows a gradient increase in the AAA wall pressure when the blood viscosity value increases.

Table 1: The rate of change in the pressure values due to the change in the viscosity values.

Normal values	**Diabetic values**	**The rate of change**
1.354e002	7.257e002	435.967%
1.389e002	2.551e002	83.657%
1.198e002	2.097e002	75.041%
9.227e001	1.393e002	50.97%
1.045e002	1.254e002	20%
9.948e001	1.119e002	12.485%

III. DICSUSSION

This study gives a comprehensive explanation of blood flowing inside the AAA. To understand thorough investigation of stress, blood flow and pressure in a diabetic patient aortic model using the CFD approach that can also predict potential regions where aneurysm can occur. We have used image based aortic geometry and blood pressure

models in control and diabetic conditions. We have found that the rate of pressure change due to the change in the viscosity values were higher in diabetic model than in control model. Similarly, AAA face a stimulating mechanical environment due to complex structure and the high flow rates in the aorta. Without prior knowledge non-Newtonian characteristics and blood viscosity are always considered, while variations in the viscosity is less healthy individuals whereas blood viscosity among diabetic patients can significantly change [13]. Aneurysm causes geometrical change of blood vessels resulting in possible detrimental outcome. As the arterial wall is affected by the blood flow and with blood hemodynamic interaction, both of these factors are primary factor for causing the wall rupture. Diabetes also cause variation in aortic hemodynamic [14]. Moreover, stiffening of the aorta is increased by the diabetes and further changes in the stiffness of the aorta make it more disposed to disease. Thus an increase in illness and higher mortality rates in diabetes patients [15, 16].

Expansion of the AAA is linked with the weakening of the wall which give rise to inflammation of the arterial wall that can possibly lead to rupture [17]. Commonly thinning and weakening of any vessel is considered as localized aneurysm mostly near or at a branch. Different biomechanical parameters and geometric factors are used to measure the possibility of the rupture making Aneurysm prediction highly difficult [18, 19]. Aneurysm rupture is the cause thousands of death annually, thus a reliable predictor for the progression of the aneurysm is still not discovered. Additionally, the diameter size, expansion rate and peak wall stress of the AAA varies from patient to patient [20]. With the help of earlier hemodynamic studies of the AAA few biomechanical mechanism related to AAA pathogenesis and development are now known [21, 22]. With the help of computational hemodynamic simulations rupture and thrombosis risk are easy to predict in comparisons to simple diameter. Computational models also have the possibility to predict the risk such as abnormal blood flow patterns, dissection, growth, rupture, and thrombus-formation based on hemodynamic parameters. Therefore, CFD is considered as an advanced tool for performing hemodynamic analysis especially for AAA studies. However, ambiguity exists for usefulness of such studies in medical fields. In our study we used same models for normal and diabetic patients with different material properties thus different results were recorded.

Idealized geometries were used in earlier studies [23, 24], however Les et al. for the first time used patient-specific CFD simulation for AAA [25]. Currently CFD studies primary focus is to determine the growth of the aneurysm with hemodynamics that can interpret intraluminal thrombus progression of the AAA [26, 27]. In contrast, earlier CFD studies were mostly focus on understanding of the flow patterns and calculating wall shear stress and presses of the AAA. Studying computational models of the aneurysm hemodynamics can help in understanding and identifying the precise factors that can rupture the vessel by enhancing the risk which can assist in clinical decisions. However, chances of error are possible with CFD studies due to variation in subject-specific boundary conditions, geometry and other modelling assumptions. Our study tends to provide a better understanding of the relationship between hemodynamic of the aorta and new aortic diseases. Further studies are required to strengthened AAA biomechanics that should be conducted to inspect the relation link between the viscosity of the blood and AAA wall pressure. Hence, if the rupture value can be determined then it is able to medically interfere on the right time before it affect the patient's life.

The concept of this research study was to improve our understanding of the intricate flow environment in AAAs as well as to expand our understanding of AAA evolution. As this CFD simulations give more detailed information on the flow of the sick human aorta, and this could help to guide decisions. Diabetic models showed significantly greater mean blood flow velocity and aortic pressure values than control models. Using the ideal 3D aortic model technology have gained an increased understanding of diabetic aortic abnormalities. Biomechanical features of the aorta linked with particular diseases enable the prediction of aortic adverse events in individuals with these disorders.

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