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ORIGINAL RESEARCH PAPER

Surgery

COMPUTATIONAL FLUID DYNAMICS ANALYSIS OF A NOVEL STENT GEOMETRY FOR CAROTID ARTERY STENOSIS.

KEY WORDS: Stent, Auxetics, Stenosis, CFD

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ABSTRACT

Aim: The aim of this research was to perform Computational Fluid Dynamics analysis of a novel auxetic stent.

Materials and Methods: Numerical results of velocity and wall shear stress were retrieved. From that the conclusion of auxetic stent interference on the blood flow was drawn.

Results: Without a stent, minimal wall shear stress was 6.14395e-03 [Pa] and maximal 3.58595 [Pa]. Blood flow velocity was minimum 9.43298e-08 [m/s] and maximum 0.224575 [m/s]. With a stent placed in the internal carotid artery, minimal shear stress was 4.494e-013 [Pa] and maximal 1.695e+001 [Pa]. Blood flow velocity with stent in place was minimum 0 [m/s] and maximum 6.634e-001 [m/s].

Conclusion: The auxetic stent has the potential to reduce the rate of restenosis and improve the quality of life among patients with carotid artery stenosis.

Introduction

The medical problem of carotid artery stenosis has sparked discussion in the medical society for the last decade [1]. Both open and endovascular approach have their benefits and pitfalls [2]. As for endovascular approach, a closed-cell stent is inserted in the carotid artery. These stents have been around for some time already and it is time for a new stent to stand up to address the issues. In this article we introduce a stent of a novel auxetic geometry for carotid artery stenosis treatment. It is based on auxetic geometry. Auxetics are those structures that have a negative Poisson ratio.

Methods and Materials

To perform a Computational Fluid Dynamics Analysis (CFD), an .stl file of a stent was built utilizing Siemens PLM Software. A real anonymized DICOM image of a patient was evaluated, carotid artery sliced with 3DSlicer 4.8 and transferred into an .stl file. So we had the environment – the carotid artery, and a stent. The computational fluid dynamics analysis was performed utilizing ANSYS Fluent 18.2. At first we had to perform meshing of the artery. In order to do that, we created virtual topology and added constraints to the automatic mesh which were inflation mesh and body sizing. As a result we had volume mesh we could use. Then we added physics to our setup. The Carreau Model for fluid viscosity was used with Time Constant, lambda 3.313 (s), Power-Law Index 0.3568 (n), Zero-Shear Viscosity 0.056 (kg/m-s), Infinite Shear Viscosity 0.0035 (kg/m-s). Density was used that of blood 1060 kg/m^3. Then the boundary conditions both for inflow and outflow were defined and Gauge Pressure 13332 Pa was set. Next step was to set particle trajectories in two injections, these particles selected as massless. Area for injections was 0.0013245 (m^2), Density 1060 (kg/m^3), Velocity 0.1 (m/s). The CFD was performed in the carotid artery environment without a stent, numerical results retrieved including velocity and wall shear stress values. In the next stage the .stl model of the auxetic stent was inserted into the internal carotid artery position and the CFD was performed under the same conditions only with the auxetic stent inserted. Numerical results of velocity and wall shear stress were retrieved. From that the conclusion of auxetic stent interference on the blood flow was drawn.

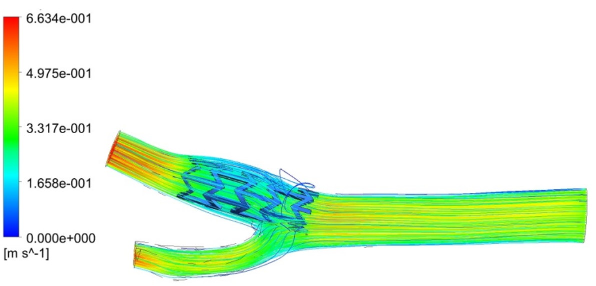

Fig. 1 Velocity with the Auxetic Stent

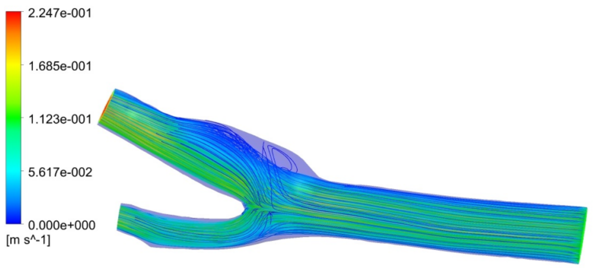

Fig.2 Velocity without the Auxetic Stent

Results

The results included values of blood flow velocity and wall shear stress of the artery both with and without a stent. Without a stent, minimal wall shear stress was 6.14395e-03 [Pa] and maximal 3.58595 [Pa]. Blood flow velocity was minimum 9.43298e-08 [m/s] and maximum 0.224575 [m/s].

With a stent placed in the internal carotid artery, minimal shear stress was 4.494e-013 [Pa] and maximal 1.695e+001 [Pa]. Blood flow velocity with stent in place was minimum 0 [m/s] and maximum 6.634e-001 [m/s].

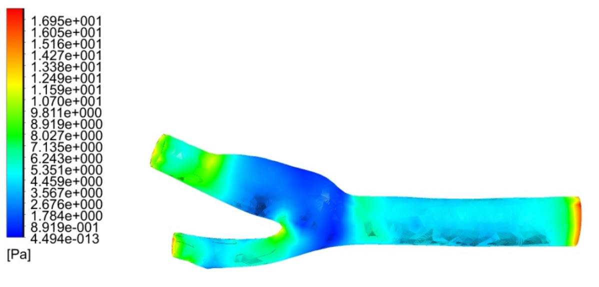

Fig.3 Wall Shear Stress with the Auxetic Stent

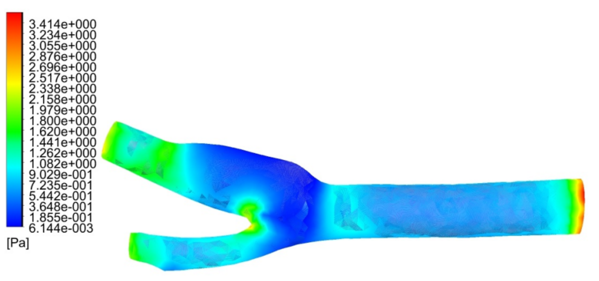

Fig.4 Wall Shear Stress without the Auxetic Stent

Discussion

We performed CFD analysis of a novel auxetic stent placed into the internal carotid artery. The difference in the velocity of blood between the environment without a stent and the environment with a stent in place is considerable. Stent auxetic has shown the potential to increase the blood velocity, hence diminish the potential for atherosclerotic plaque formation. It is well known that low blood velocity is essential for plaque formation and increases the rate of stroke in the population [3].

The difference in the rate of wall shear stress is also prominent. With stent in place the area with low shear stress, which is believed to be associated with plaque formation, is much smaller [4]. Not only does the auxetic stent increase velocity, but also improves wall shear stress in such a way that conditions for plaque formation are unsuitable.

Conclusion

We are pleased with the results of computational fluid dynamics analysis of the novel auxetic stent and can claim that it has the potential to reduce the rate of restenosis, increase the blood flow to brain and improve the quality of life among patients with carotid artery stenosis.

Acknowledgements

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