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A STUDY OF BIOMECHANICAL BEHAVIOUR OF FENESTRATED CAPILLARIES IN THE GLYCOCALYX OF GLOMERULUS

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Abstract- Prognostication of biomechanical behaviour of blood flow in glomerulus is very much necessary to design and construct an artificial kidney under normal conditions. Each kidney contains about 1 million filtering unit (glomeruli). The glomeruli consist of three layers. The glomeruli are made up of many microscopic clusters of tiny blood vessels (capillaries) with small pores. In this work an endeavour is made to find out the characteristics of capillaries when the glomerular filtration is done. The pores (fenestrae) of these capillaries are more responsible for the variation in glomerular filtration rate (GFR). For this analysis, first the artificial model of structure was constructed using Autodesk Inventor software, consisting of 3 parts (Afferent arteriole, Efferent arteriole, Capillaries).The velocity of blood flow in the capillaries and pressure exerted by the blood on the walls , wall shear stress of the capillaries were found out using ANSYS 15.0. This model will help in understanding the characteristics of capillaries while the blood flow occurs for the filtration during glomerular filtration in both normal and diseased conditions..

Keywords— Nephron; Glomerulus; Capillaries; GFR; Afferent arteriole; Efferent arteriole.

1.INTRODUCTION

The nephron is the major part of kidney which plays a major role in urine formation. The human body consists of 2 kidneys each kidney consists of millions of nephrons. Glomerular filtration, Tubular absorption and tubular secretion are the most important 3 process that took place in nephron during urine formation. In this glomerular filtration is most important one were the removal of unwanted particles to the tubule will take place. The glomerular filtration occurs in capillaries of glomerulus which consists of three layers. The endothelial cells of glomerulus, glomerular basement membrane and podocytes. In this the endothelial cells which consists of pores. These pores in the capillaries are responsible for the glomerular filtration which ranging from 30-40nm. A computational analysis of blood through the capillaries were analysed here using the simulation software (ANSYS). A 3d model using Autodesk Inventor software is being constructed and imported in the ANSYS software for the analysis purpose. This analysis will lead to understand the blood rehology in Afferent and Efferent arterioles as well as in the capillaries .The biophysical changes to the blood in capillaries of glomerulus that occur during the urine formation is very much necessary while modelling an artificial kidney.

2.METHODOLOGY

Geometry construction is the most important part of the simulation process. The geometry modelling is carried out by the Autodesk Inventor software which is easy to handle the 3-D model. The model mainly consists of 5 parts afferent arteriole, Efferent arteriole and 3 capillaries which consist of pores. The extended cylindrical tube is adjusted and assembled to develop the geometry. After the geometry construction the model is being imported to the ANSYS software for the further analysis. The analysis process is carried out by the Meshing were inlet and outlet identifications being done. After that for the fluid flow analysis fluent software is used. The laminar flow model is used for this analysis purpose. The model is spitted in to the five cell Zones were three of zones (capillaries) are enabled by the porous zone. The fluid material that used to flow in the model is blood which consists of definite properties.

3.DESIGN AND DEVELOPMENT

For the design criteria the most important is dimensions of the geometry. The recent advancement in the radiological imaging helps to know about the dimensions of the model. The Autodesk Inventor software is more important in this project were the design is being builded with certain limitations. Here the afferent arteriole, efferent arteriole and bowman's capsule were separately constructed and

then the assembling is being done. The model is being illustrated in the figure: 1.The Bowman 's capsule which consist of capillaries which is showed in the figure: 2.The dimensions of the geometry is showed in the Table: 1

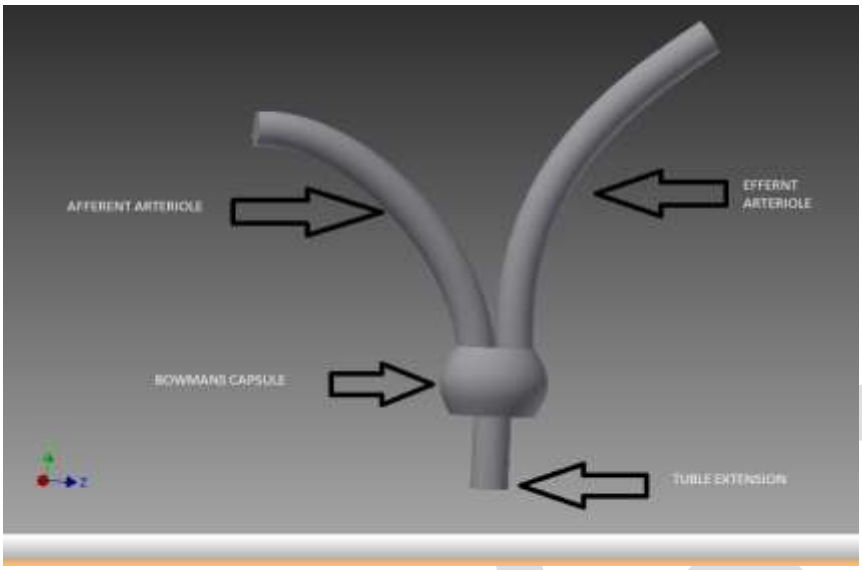


Figure1: The glomerulus model which is constructed using the Autodesk Inventor software.

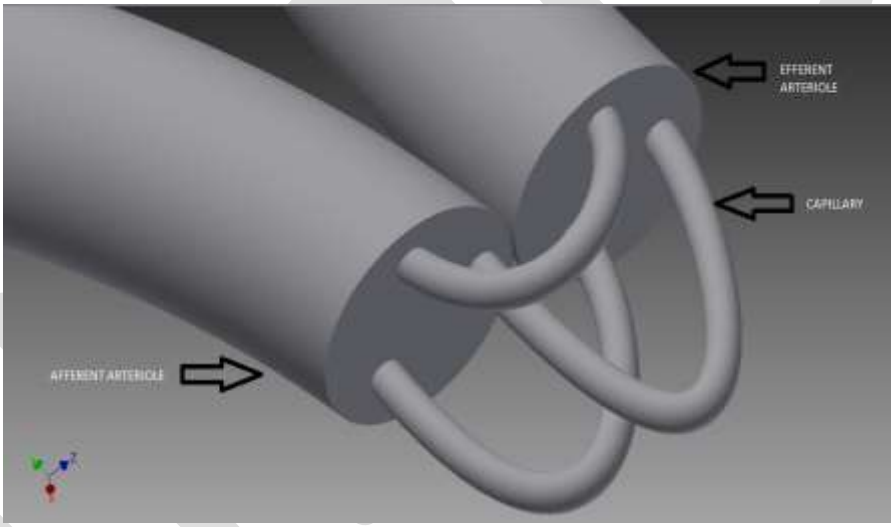


Figure2: The model which is showing capillaries connection between the afferent arteriole and efferent arteriole

3.1 DIMENSIONS OF THE GEOMETRY

PART	LENGTH	RADIUS
AFFERENT ARTERIOLE	45mm	5mm

EFFERENT ARTERIOLE	45mm	5mm
CAPILLARY 1	0.30mm	0.8mm
CAPILLARY 2	0.30mm	0.8mm
CAPILLARY 3	0.35mm	0.8mm

3.2 FLUID FLOW ANALYSIS OF THE GEOMETRY

The step after the geometry construction is the meshing of the model .For that the meshing of the model is being carried out by the meshing software .The inlet and the outlet of the fluid flow is marked for the further reference and it is showed in figure 3.

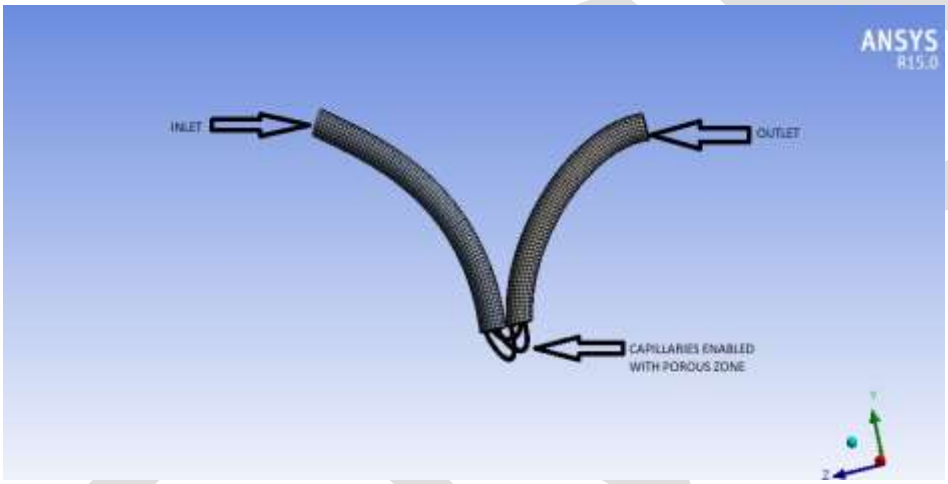


Figure3: Meshing of the geometry for the further reference of fluid flow analysis

4.SETUP CONSIDERATIONS

The setup considerations being started using the fluent software. Here the laminar flow is being selected for the analysis. The fluid here is created for the flow which shows the properties of the blood .Here there are five parts were two are arterioles and three are capillaries which were enabled by the porous zone using cell zone conditions. And the porous zone values were assigned in the boundary conditions

5.RESULT

1.PRESSURE VARIATION ACROSS THE CAPILLARIES

Figure4: Contours of static pressure (Pascal) is illu strated

2. VELOCITY VARIATION ACROSS THE CAPILLARIES

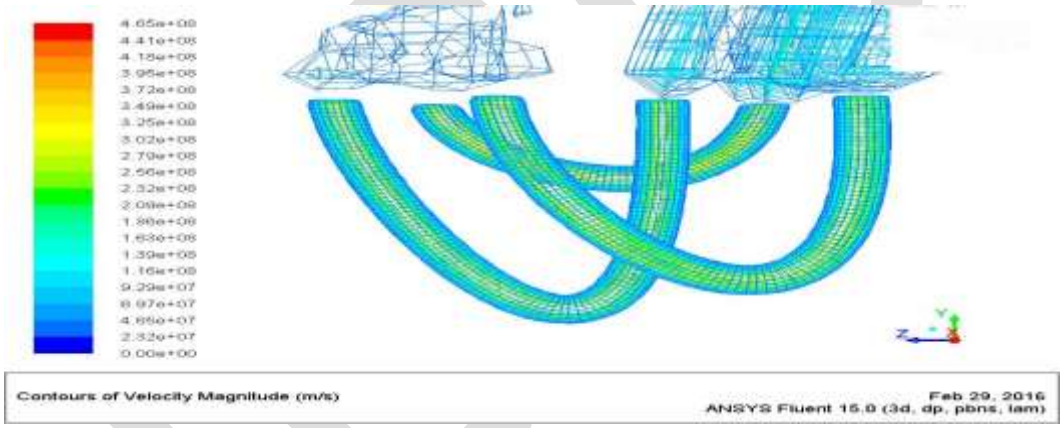
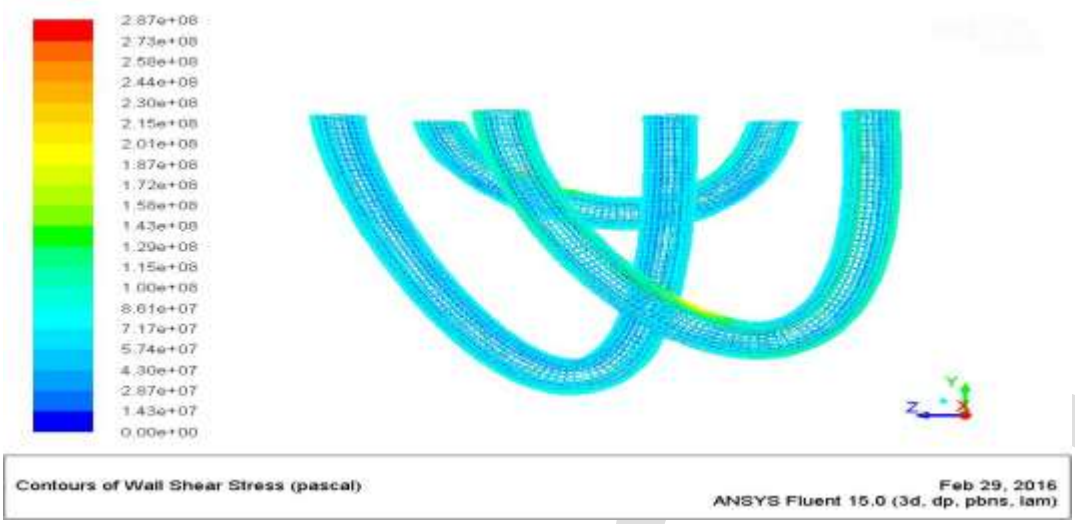


Figure5:Contours of velocity magnitude(m/s) is illustrated

3.WALL SHEAR STRESS ACROSS THE CAPILLARIES



6.CONCLUSION:

This paper describes the physical properties of capillaries that is responsible for glomerular filtration across glomerular layer. Here the velocity, pressure and the wall shear stress across the capillaries is being found. The static pressure is high when the blood enters the capillaries and gradually it decreases when it enter in to the efferent arteriole. The velocity in the arteriole is 0- 9029e+07 and when the fluid reaches the capillaries it get increased to3.25e+08.So the velocity is much more higher in capillaries when compared with the arterioles. The wall shear stress in the capillaries will be more in the surface layer so that the filtration made easier for the removal of particles

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