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Lumped Modeling of Bifurcation – Cerebral Arteriovenous Malformation

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ABSTRACT
Cerebral Arteriovenous Malformation (CAVM) hemodynamic in disease condition results changes in the flow and pressure level in blood vessels. This can cause rupture or decreased blood supply to the tissue through capillary causing infarct. Measuring flow and pressure without intervention along the vessel is big challenge due to occlusion, bending and thinning of the vessel in Arteriovenous Malformation patients. In this paper, we proposed a lumped model for the Bifurcation for symmetrical and asymmetrical networks that will help doctors to find the pressure measurements non-invasively.

Keywords
Bifurcation. LumpedModel, AVM, Hemodynamics, Electrical Modeling.

1. INTRODUCTION
In a normal brain, the blood flow is from arteries to veins through a capillary bed. In the case of arteriovenous malformation (AVM) condition, the normal blood flow is affected and there arteries are directly connected to veins without a capillary bed, forming a tangle of abnormal blood vessels. The central part of the malformation consisting of tangled abnormal vessels is called 'Nidus'. There is very low pressure in the AVM; hence a large amount of blood is drawn into this. Due to this there is a lot of pressure built up in the blood vessels, especially in the veins. The risk of rupturing of the veins draining the malformation is high because veins cannot handle as much blood pressure as that of arteries.The need for modeling is to help Doctors to take preventive steps and for early diagnosis for the risk of rupture and treatment planning for the AVM patients .The figure 1.0 shows the AVM data, which is very complex in structure to model:

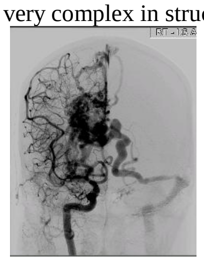
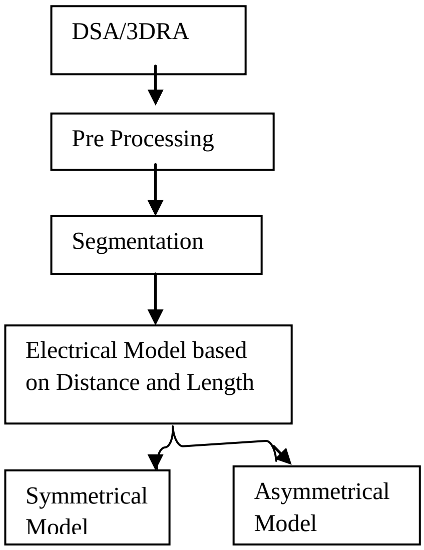


Figure 1.0 – AVM

In the literature, there are various papers representing the bifurcation for various organs based on the mechanical property of the blood flows, where they have not considered the some clinical parameters for the modeling. In this paper, we proposed the modeling for the segment of the bifurcation by navigating through the complex vessels. The bifurcation is combination of Asymmetric and Symmetric bifurcation based on the clinical parameters of the blood vessels and model output is based on the segmented vessels. The model is based on the 2D and 3D image, where we used Digital Subtraction Angiogram (2D) and 3D-Rotational Angiogram (3D-RA) as the input data.

2. METHODOLOGY
The following are the methodology used to implement the bifurcation model for the blood vessel:



2.1 Preprocessing:
The input image used is 2D/3D image of imaging modality DSA/3D-RA. The image is preprocessed using FFT, Image enhancement and smoothing of the image is performed, that helps to find the accurate distance and length of the vessels.

2.2 Segmentation
The preprocessed image is then segmented using OTSU segmentation and vessels are extracted for each compartment of the vessels and each compartment of the vessels are analyzed and modeled using lumped model.

2.3 Electrical Model:
The electrical model is based on the model was based on the principle of electrical networks -Kirchhoff's voltage law (KVL) and the concept of R-L-C device models is constructed using windkessel model and RLC combination is based on

the length and distance of the vessels. The diameter and length variation determines the R-R,R-L,R-C,RLC combination to simulate the exact vessel construction. The pressure and flow rate is determined by the voltage and current.

2.4 Bifurcation Model:

The Bifurcation of the vessels is of two types – Symmetrical and Asymmetrical. The symmetrical bifurcation is the one which has equal split of the branch angle from the parent node as shown in figure 2.0.

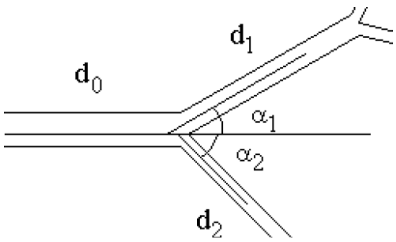


Figure 2.0 Bifurcation Angle

For asymmetrical bifurcation the angle between the branch angle is not equal and also the distance and length of unequal length and distance. The lumped model for the symmetrical bifurcation with equal length and distance is shown in figure 3.0:

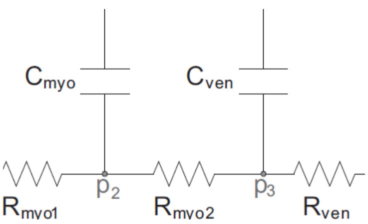


Figure 3.0 Symmetrical Bifurcation

For asymmetrical bifurcation the angle between the branch angle is not equal and also the distance and length of unequal length and distance. The lumped model for the symmetrical bifurcation with equal length and distance is shown in figure 4.0.

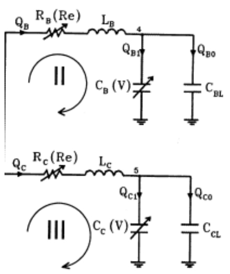


Figure 4.0 Asymmetrical Bifurcation

3. RESULTS & DISCUSSION

The lumped model is implemented using MATLAB – SIMULINK. The input pressure at feeding arteries is simulated using electrical parameters and the results are validated using Mechanical outputs. The clinical parameters are converted to voltage and current and simulated with RLC networks, the complete electrical network is shown in figure 5.0.

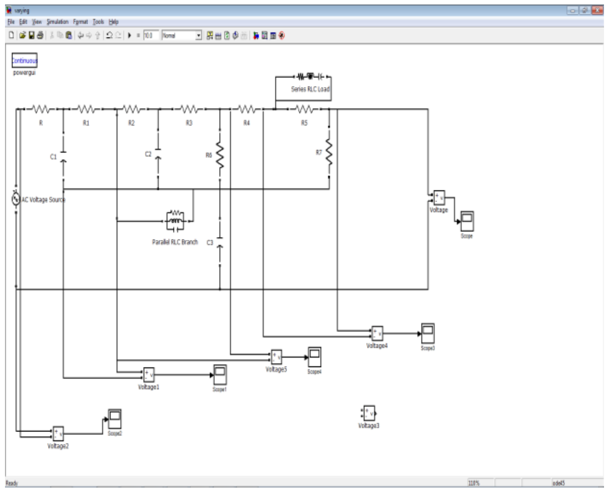


Figure 5.0 Electrical Model of Bifurcation

The electrical model is validated with clinical outputs supported by the Radiologist, the pressure values are validated with model outputs as voltages.

4. CONCLUSION

In this paper we proposed Bifurcation modeling of the AVM, we have provided a rigorous approach for electric circuits whose physical constants (R, L and C), are parameterized on the standard length of the vessel using normals in order to recover correct values for pressure or flow-rate at Bifurcations for AVM patients. This work is in progress to model complex networks with complex bifurcation analysis.

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