BLOOD FLOW SIMULATION IN AN ARTERIO-VENOUS FISTULA

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INTRODUCTION

Patients with ESRD "end stage renal disease" require haemodialysis. Its most desirable form of vascular access is the arterio-venous fistula. We propose an investigation protocol to understand the correlation between hemodynamic changes in this very specific blood vessel and the associated clinical complications. Realistic 3D reconstruction geometry of the fistula is the result of segmenting CT angiography images. Then the geometrical model is treated with industrial computation fluid dynamics software for blood flow simulation.

METHODS

A non pathologic fistula realized in 1987 is the base for this study. CT images are therefore acquired using "Lightspeed Ultra CT, General Electric" & the smartPREP technology. The images are then exported in a DICOM format. Vessel contour segmentation is the output of the region growing algorithm to be finally reconstructed into a three dimensional volume by applying "NURBS". This volume is introduced into Gambit 2.1® (Fluent, Lebanon, NH, USA) to produce the biomechanical model. At the entrance of the fistula (arterial side), a straight tube of sufficient length is added to allow the blood flow profile development. The volume is perpendicularly divided into seven sub-volumes taking into consideration the vascular central axis as a reference. Each face of the sub-volumes has been meshed with a 524 quadrilaterals at the input & at the output. A boundary layer at the wall of four rows has been added to calculate the velocity gradients & wall shear stress. The Cooper algorithm is implemented to propagate into the volume meshing it with hexahedral mesh of total number 150 288[1]. The blood flow in the vessels of the meshed biomechanical model is calculated using Navier-Stokes equation solved using Fluent 6.1® (Fluent, Lebanon, NH, USA). The post treatment and interpretation of the results are affected using Ensith7.6® (CEI, Apex, NC, USA). In such vessels the blood is considered a Newtonian fluid of viscosity 0,004 Pa.s and density of 1050 kg/m3 [2]. In our study, a non stationary flow of a cardiac frequency 76 beats/ minute with a period of (0,8 sec) is applied. The entrance velocity follows the physiological curve presented in the literature [3].

RESULTS AND DISCUSSION

As a result of the numerical simulation, the non stationary flow enables flow pattern visualization during the cardiac cycle in the artery, anastomosis & vein. Figure 1a & 1b shows respectively an axial & a sagittal plane of the arterio-venous fistula at two different cardiac instants.

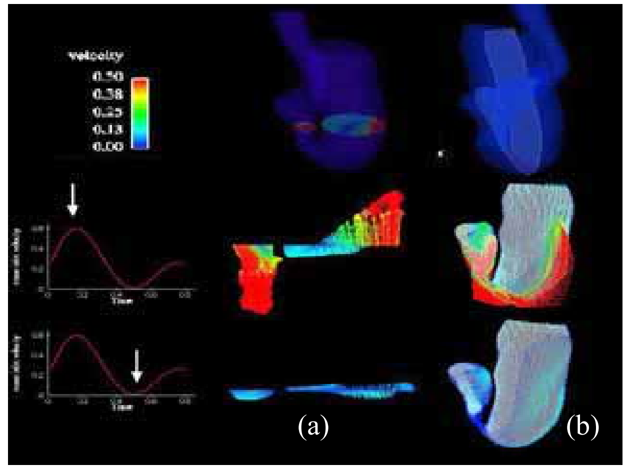

Figure 1: (a) velocity profile axial plane. -(b) velocity profile sagittal plane of the anastomosis

In the axial plane we can notice the parabolic velocity profile in the artery. Whereas in the vein, we see a partial inversion of the velocity profile at the systolic peak. At the beginning of the diastole, there is low velocity. For the sagittal plane we can see a jet towards the external wall of the vein due to the acceleration at the anastomosis, which produces constraints over the wall of the vein and noticeable recirculation phenomena at the low velocity zone at the interior.
We validate our results by comparing it to an Echo-Doppler examination for the same patient. We measure the flow at the artery and visualize approximated velocity profiles at different cross-sections. The obtained flow representation is less accurate than our method. In addition our simulation allows wall shear stress calculation which can not be obtained in the Doppler study.

CONCLUSIONS

The simulation indicates the risk zones, weak shear rates & views of the recirculation zone. The obtained flow representation is more precise than the Doppler velocity measurements. Therefore our method represents for the clinicians an additional tool to prognostic and diagnosis. Indeed low constraints may predict atherosclerosis generation and high constraints may lead to potential changes in the venous shape serious structural changes

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