PROJECT REPORT

EFFECT OF THE ANASTOMOTIC ANGLE IN ARTERIOVENOUS FISTULA ON THE INDUCED HEMODYNAMICS

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Project Goals and Objectives:

Our goal was to study the effects of the configuration of AVF, namely the anastomotic angle, on the corresponding hemodynamic parameters. The goal was accomplished through the following objectives:

1. To obtain an understanding of the field both in regards to our group’s prior research and other studies.
2. To create a relevant AVF model and vary the angle of connection between the vein and artery.
3. To calculate the flow fields.
4. To obtain data for the hemodynamic parameters in each case along important points.
5. To analyze that data to determine which model has more favorable fluid flow.

Research Tasks:

In order to accomplish our objectives, we had research tasks. The first was to read articles from the relevant field given to us by our graduate mentor. I collected this information in a paper format divided into sections based on topic. By doing so, I obtained an understanding of the background information to the topic including how hemodynamics effect vascular remodeling and why AVFs fail to mature. Following the introductory phase, the geometry of the fistula configurations was explained to us by our graduate mentor and models given. The discussion of the geometry and the effects it should have on the fluid flow can be seen in pictures 1, 2, 3, and 4. Ken and I then extracted data from the model to analyze.

Methodologies and Results:

Based on our lab’s previous experimental data on an in-vivo porcine model, a computerized AVF model with a 90° anastomotic angle and one with a 60° anastomotic angle were created. An unstructured grid was generated for each arteriovenous fistula (AVF). The numerical domain was solved using control volume techniques to obtain the flow field within each AVF under steady state condition. Velocity boundary conditions were applied at the proximal and distal arteries, and an outflow condition was specified at the outflow vein. The flow rates at the proximal and distal arteries were also chosen based on our in-vivo porcine experiments with corresponding Reynolds numbers of 1464 and 508, respectively.

In both AVFs, recirculation zones formed along the inner bends of the curved segment of the vein resulting in negative axial wall shear stress (WSS) in those locations. Ken Okoye can be seen analyzing these flows in Picture 5. This zone was larger for the 60° AVF as it extended to the straight segment of the outflow vein, while it was limited to the curved region in the 90° case. The 60° AVF had the greatest magnitude of negative WSS (= -130.19 dyne/cm²) on the inner bend relative to the 90° case (= -55.16 dyne/cm²). Additionally, the highest positive axial WSS was found on the side wall of the 60° AVF (= 354.33 dyne/cm²) as compared to the 90° case (= 342.76 dyne/cm²). In Pictures 6 and 7, Ken and I are looking at the WSS contours we created for one fistula model. Although the velocity patterns and WSS distribution in the two cases followed similar general trends, WSS levels and the length and strength of the recirculation zones differed. These differences can increase the possibility of future complications such as venous stenosis in one case as compared to the other as noted in the literature review.

Training Received:

To understand our project and produce results, our graduate mentor taught Ken and I about some software. Gambit was used to create the model that was then exported to Fluent, the process of which we were familiarized with. After the mesh was numerically solved in Fluent, we used CFD Post to collect data. The majority of our training lay in CFD Post with different means of collected data, by plotting lines, contours, charts, streamlines and more to look at different aspects of the flow. CFD Post is being used in Pictures 5, 6, and 7.
The data was then exported into Excel to perform calculations and to create plots. I already knew how to use this software, however I learned how to make format plots in a way that they are widely accepted in papers and a few helpful tricks along the way.

Conclusions:
After careful analysis of the results, we concluded that the 90° AVF with less reversed flow along the inner bend and lower potentially damaging high WSS on the outer wall seemed to have more advantageous hemodynamic parameters. Furthermore, substantial variation in the flow profiles with anastomotic angle showed that the surgical configuration of an AVF has a considerable effect on its hemodynamics and thus the eventual maturation or failure of the access. Consequently, proper attention to this very important factor can have a significant effect on the dialysis patients' health care.

Although the results showed the effects of configuration on the hemodynamics patterns of AVFs, the analysis was based on a simplified model and thus, could not represent a clinical case. Nonetheless, these models can provide important insight into the factors that determine the vascular remodeling needed for hemodialysis. Other anastomotic angles can also be analyzed to confirm the trends in hemodynamic parameters identified in this study. Additional hemodynamic parameters can also be investigated in further studies as well.

Pictures:
Picture 4: Briana Conners draws the fluid flows expected in the model AVF due to its geometric configuration.

Picture 5: Ken Okoye plots streamlines in CFD Post to visualize flow along the bend.
Ken Okoye and Briana Conners look at the WSS contour in CFD Post to determine the effects it would have on fistula maturation.