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Numerical simulations of an anti-thrombus inferior vena cava filter with CFD and FSI

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Inferior vena cava (IVC) filters have been used to prevent recurrent pulmonary embolism in patients who are at very high risk, who are unresponsible to anticoagulation therapy, or in whom anticoagulation is contraindicated [1]. IVC filters are used to intercept and trap large clots while allowing clot-free blood to pass freely towards the heart.

It is important to understand how the inferior vena cava behaves and how the insertion of the filter inside the vena affects the hemodynamics of the vena.
For that reason, a hemodynamic study of the IVC using computational fluid dynamics (CFD) analysis is performed and the interaction between blood and the vena tissue using fluid structure interaction (FSI) is studied.

CFD is used to solve wide-ranging fluid flow problems. When using computational fluid dynamics the vena cava is designed as a rigid body and deformations of the wall are not taken into account. CFD is a great tool for performing numerical analysis and study how fluid flow performs inside of a solid, and around the filter [2].

In order to validate that the numerical solutions are correct, in-vitro experiments have been previously performed and have confirmed that the software is accurate for the model, as shown in Figure 1.

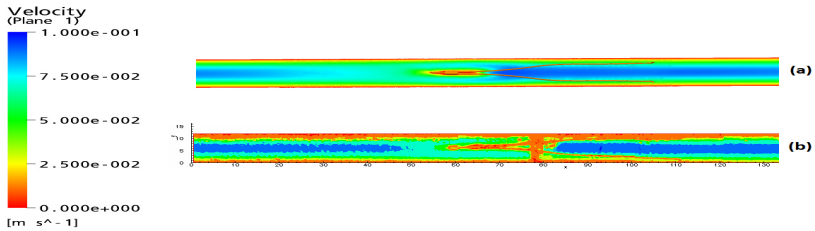

Figure 1. Numerical-experimental comparison of the flow fields of a vena cava model with the filter inserted.

Because the numerical model was compared with an experimental model, there are some variations in the model with respect to a real vena cava. A simplified model of the inferior vena cava has been designed and a four-legs Günther Tulip filter has been used for the

simulations. To generate the geometry of both the vena and the filter, the software SolidWorks has been used. The finite element mesh has been created using ANSYS ICEM and finally the CFD analysis has been done using ANSYS CFX. The material used for the vena is silicone and a flow rate of 383 mL/min is applied. The flow used has similar properties to blood and is laminar and steady. Additionally, a model that includes a thrombus when is being trapped by the filter has also been studied. Figure 2 and 3 show the wall shear stress seen in both models.

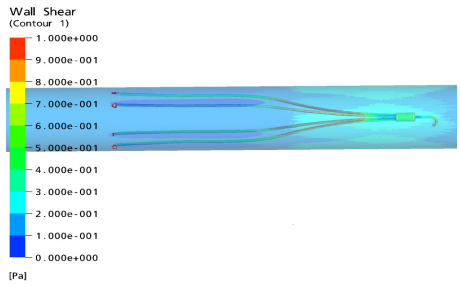

Figura 2.WSS for the CFD model with filter

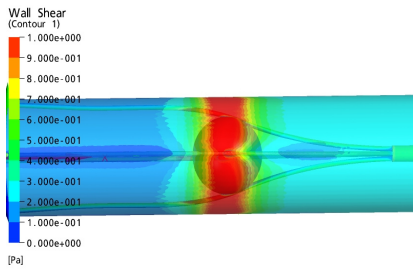

Figura 1.WSS for the CFD model with thrombus

In order to go a bit further and study the possible deformations that the vena wall may experiment, FSI analysis has been done. In an FSI calculation, the solid surfaces act as interfaces between the fluid and solid domains to provide transfer of loads- mechanical. The CFD solution provides unsteady flow field solutions for pressure on solid surfaces, then the FEA solver calculates solid deformations based on the CFD results.
For the FSI analysis the software ADINA has been used. The same flow rate has been imposed at the inlet, and the pressure used in the experimental model has been imposed at the outlet. The fluid-structure interaction between blood and the vena tissue has been analyzed.

When analyzing the results, it has been observed that the deformations of the silicone simulated vena cava are very small and it has been shown that both CFD and FSI models are capable of simulating and characterizing the hemodynamics of the vena cava and the interaction between the fluid and the solid models.
Once the models are validated, the next step is to analyze patient-specific geometries with FSI to study the damage of the vena wall and the fluid dynamic in patients' IVC.

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