Modelling of a Textile Endovascular Graft in an Aneurysm with Clot Formation: a Multi-Scale Approach

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ABSTRACT

Textile endovascular grafts are one of the main treatments to prevent rupture from abdominal aortic aneurysms, restoring the normal blood flow and shielding the weakened aneurysm wall. It is believed that the success of a textile endovascular graft, in the healing process after implantation, is due to the porous micro-structure of the wall. Among the key properties that take part in the tissue repair process are the type of fabric and degree of porosity and permeability. The performance of a textile endovascular graft is determined by several functional requirements such as: fluid control, physical barrier, different levels of penetration of the cells, among others. However, when an artificial wall of the graft is first exposed to blood, a process of activation, adhesion and aggregation of platelets will begin, which may form a platelet plug that occludes the graft. One of the possibly reasons of graft thrombosis may be due to the response to the implantation of a foreign material for the lack of endothelium.

The aim of this work is to model the flow pattern and the fluid-particle interaction, which include activation, aggregation and adhesion of platelets, in a duct with an aneurysm geometry and a textile wall of endovascular graft. The numerical process is based on a multi-scale approach, which couples the Finite Element Method (FEM) and a Particle-Based Technique. Fluid flow is modelled by FEM and the discrete particles are modelled adopting a Molecular Dynamic method. Both methods are coupled through the force terms. For this issue, the artificial wall of textile graft is defined with a fictitious domain model and is evaluated with different porosities. The fluid-particle interaction is accomplished in two and four-ways. The results have shown that the textile wall with different porosities, acting like a barrier between the blood and a zone with an idealized aneurysm, affect the flow pattern, the number of platelets adhered to the artificial surface and the time of residence of platelets inside the aneurysm zone. In conclusion, the development of new textile grafts may be improved if details of the flow pattern and the mobility of blood cells through the graft wall are known and predictable, before the graft is manufactured.

Keywords: textile endovascular grafts, porous media, computational fluid dynamics, fluid-particle interactions, multi-scale approach, Abdominal Aortic Aneurysms (AAA)

REFERENCES

[1] Abdessalem, B., Durand, B., Akesbi, S., Chakfe, N., And Kretz, J. Fluid structure interaction in a free end textile vascular prosthesis. The European Physical Journal Applied Physics 31 (2005), 211–216.

[2] Angot, P., Bruneau, C., And Fabrie, P. A penalization method to take into account obstacles in incompressible viscous flows. Numerische Mathematik 81, 4 (1999), 497–520.

[3] Contro, R., And Vena, P. Computational models for biological tissues and biomedical implants. Engineering Computations 20, 5-6 (2003), 513–523.

[4] Dobrich, O., Gereke, T., And Cherif, C. Modelling of textile composite reinforcements on the micro-scale. Autex Research Journal 14, 1 (March 2014), 28–33.

[5] Ehrhardt, M. An introduction to fluid-porous interface coupling. Progress in Computational Physics : "Coupled Fluid Flow in Energy, Biology and Environmental Research" 2, 10 (2010), 3–12.

[6] Glowinski, R., Pan, T., Hesla, T., And Joseph, D. A distributed lagrange multiplier/fictitious domain method for particulate flows. International Journal of Multiphase Flow 25, 5 (1999), 755 – 794.

[7] Kojic, M., Filipovic, N., And Tsuda, A. A mesoscopic bridging scale method for fluids and coupling dissipative particle dynamics with continuum finite element method. Computer Methods in Applied Mechanics and Engineering 197 (2008), 821 – 833