

# NUMERICAL MODELING AND SIMULATIONS OF BLOOD FLOW IN SIMPLIFIED AND REALISTIC ARTERIAL GEOMETRIES: TOWARDS OPTIMIZED MAGNETIC DRUG DELIVERY

## PROJECT AIM

One of the main problems of chemotherapy is often not the lack of efficient drugs, but the inability to precisely deliver and concentrate these drugs in affected areas. Failure to provide localized targeting results in an increase of toxic effects on neighboring organs and tissues. One promising method to accomplish precise targeting is magnetic drug delivery. Here, a drug is bound to a magnetic compound injected into the blood stream. The targeted areas are subjected to an external magnetic field that is able to affect the blood stream by reducing its flow rate. In these regions the drug is slowly released from the magnetic carriers. Consequently, relatively small amounts of a drug magnetically targeted to the localized disease site can replace large amounts of the freely circulating drug. At the same time, drug concentrations at the targeted site will be significantly higher compared to the ones delivered by standard (systemic) delivery methods. We believe that mathematical modeling and numerical simulations can significantly contribute to further advancements of this technique.

## PROGRESS

We have developed a comprehensive mathematical model for simulations of blood-flow under the presence of strong non-uniform magnetic fields. The model consists of a set of Navier-Stokes equations accounting for the Lorentz and magnetization forces, and a simplified set of Maxwell's equations (Biot-Savart/Ampere's law) for treating the imposed magnetic fields. The relevant hydrodynamic and electro-magnetic properties of human blood were taken from the literature. The model is then validated for different test cases ranging from a simple cylindrical geometry to real-life right-coronary arteries in humans. The time-dependency of the wall-shear-stress for different stenosis growth rates and the effects of the imposed strong non-uniform magnetic fields on the blood flow pattern are presented and analyzed. It is concluded that an imposed non-uniform magnetic field can create significant changes in the secondary flow patterns, thus making it possible to use this technique for optimisations of targeted drug delivery.

## DISSERTATIONS

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## SCIENTIFIC PUBLICATIONS

1. Kenjeres, S. (2008), "Numerical analysis of blood flow in realistic arteries subjected to strong non-uniform magnetic fields", *International Journal of Heat and Fluid Flow*, Vol.29 (3), pp.752-764.
2. Kenjeres, S. and Opdam, R. (2008), "Computer Simulations of a Blood Flow Behaviour in Simplified Stenotic Artery Subjected to Strong Non-Uniform Magnetic Field", *Proceedings of the 4th European Congress for Medical and Biomedical Engineering, Engineering for Health, EMBC 2008, 23-27 November 2008, Antwerp, Belgium*, pp.1-4.
3. Haverkort, J. W. and Kenjeres, S. (2008), "Optimizing drug delivery using non uniform magnetic fields: a numerical study", *Proceedings of the 4th European Congress for Medical and Biomedical Engineering, Engineering for Health, EMBC 2008, 23-27 November 2008, Antwerp, Belgium*, pp.1-4.

## PROJECT LEADERS

S Kenjeres

## RESEARCH THEME

Complex dynamics of fluids  
Mathematical and computational  
methods for fluid flow analysis

## PARTICIPANTS

S Kenjeres

## COOPERATIONS

ERASMUS MC Rotterdam,  
ETH Zurich

## FUNDED

TU Delft  
1<sup>st</sup> 100% 2<sup>nd</sup> - 3<sup>rd</sup> -

## START OF THE PROJECT

2006

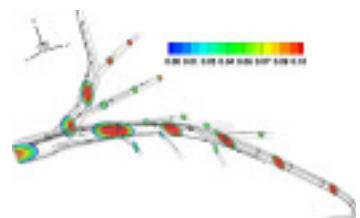
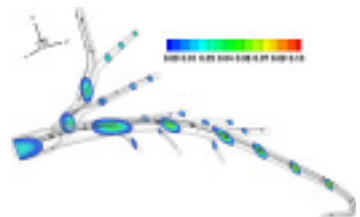
## INFORMATION

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Streamtraces and contours of the velocity magnitude in a realistic multi-branching human left-coronary artery during a heartbeat pulsating cycle, Haverkort and Kenjeres (2008). Left-  $t=0$  sec, Right-  $t=0.8$  sec.