break the symmetric flow pattern of the secondary motion in the host vessel. The peak value of WSS shifts away from the bed to the lateral wall. At peak systole and end systole, flow shows little difference due to similar viscosity at high shear rate. Notable difference, however, is observed at other times. The OSI is analysed with the spatial and temporal WSS distribution for correlation to intimal thickening. Downstream of the toe, flow demonstrates higher OSI and low WSS, corresponding to restenosis observed there experimentally. We conclude that the shear thinning effect of blood is a key factor to be considered with the geometry of blood vessel when investigating the relation between blood flow and vascular diseases.

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6831 Th, 11:45-12:00 (P42)

Flow instability in a failed brachio-cephalic graft for hemodialysis: A computational study

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We present a CFD case study on a brachio-cephalic loop graft for hemodialysis. The graft presented a kink on the venous side and developed wall thicknening and multiple stenoses downstream the kink. As a consequence, the patient experienced a flow reduction from 1320 ml/min to 650 ml/min, which was considered as predictive of thrombosis and required preventive treatment. Prior to the endovascular treatment, the patient underwent a 3D CE-MRA evaluation. A 3D model of the graft geometry was generated from the MR dataset by means of a level set approach. One model representing the whole graft and one partial model of the sole kink were created. In both cases, cylindrical flow extensions were smoothly joined to the model ends, and fine quadratic tetrahedral meshes were generated. Computational fluid dynamics simulations were carried out using a semi-implicit solver based on a second order operator integration factor approach with Lagrangian treatment of the convective terms. Fully developed flow was imposed at the graft inlet in two sets of simulations, at 1320 ml/min and 650 ml/min respectively. After an initial washout time, the simulations were advanced in time for 0.05 s in 4800 timesteps.
At 650 ml/min, flow is laminar in the whole loop graft, but the presence of the kink induces strong secondary flow patterns in the downstream sections. At 1320 ml/min, flow is laminar from the inlet to the level of the kink, including the loop. However, unsteady fluctuations appear past the kink and persist several diameters downstream. The phenomenon is studied in fine detail in the partial model, on which mesh and timestep refinement studies have been performed. Transitional flow has been demonstrated to have an adverse effect on the vascular wall, activating intimal hyperplasia and leading to graft failure. In this study, we show how such conditions can take place in loop grafts at physiologic flow rates in presence of a kink, and how this might have led to stenosis development in the patient's case.

6228 Th, 12:00-12:15 (P42)

Mathematical modeling of blood flow in an arterial bypass anastomosis

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The Paper presents a mathematical tool to investigate the fluid dynamics in an Arterial bypass anastomosis. We consider both the stenosed artery as well as the bypass graft to study the flow behavior of blood. Due to elastic deformation of vessel wall, Navier-Stokes equations for pulsatile flow in elastic tube are considered to study the flow parameters. Results are discussed numerically depending on the values of Reynolds number, angle of bypass and occlusion position of host artery and compared with the available results.

6784 Th, 12:15-12:30 (P42)

Simulation of macromolecules transport within the arterial wall and links to atherogenesis

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The field of atherosclerosis pathology is an important area of research. Recent research has concentrated on chemical and molecular mechanisms. Arterial wall is mainly consisted of three distinct regions. Tunica media is separated from tunica adventitia by an internal elastic lamina (IEL), which is a fenestrated layer of elastic tissue. In this study, we have used a two-dimensional numerical model to investigate the transport of macromolecules such as ATP, LDL and other species with different mass diffusivity coefficients and their distribution in the tunica media in the present of IEL. We have studied their distribution individually, in the absence of other molecules, and in a more real situation that is a combination of the presence of different molecules, a new study that hasn't been mentioned in the previous published works. In fact, the final situation is a balance between different species distribution. Macromolecules penetrate in the media by three controlling process: diffusion, convection and SMC surface reaction. The final distribution is a balance between these three different mechanisms.
Tunica media is considered as a saturated porous medium with a Darcy permeability coefficient. SMCs are modeled as an array of cylinders. IEL is an impermeable barrier to the solute and solvent penetration except in the pores. Pores distribution is assumed uniform.
The governing equation for fluid flow in the media is Brinkman's equation. Mass transport equation is used for macromolecules penetration. SMCs surface reaction equation is imposed as a boundary condition.
Results show an interesting demonstration of concentration contours for different species. For ATP dominant concentration mechanism is diffusion in contrast to LDL that is convection. Compare these contours with surface reaction contours, surface reaction effect is much clearer in a diffusion dominant mechanism. Their combination shows a very interesting result. In addition, streamlines help us to follow the distribution path. All these play an important role in detecting atherogenesis.

T1.5 Computational Biomechanics and Mechanobiology of the Heart

7686 Th, 14:00-14:15 (P44)

Flow and blood shear stress in a chicken embryonic heart, experiments and numerical modeling

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There is evidence that there is a connection between the shear stress distribution at the wall of the developing, embryonic heart and growth errors. This relationship needs to be verified and quantified using experiments and a numerical model. This is done for an embryonic chicken.
Some experiments use shear stress responsive DNA to identify positions with high and low shear [1]. Moreover, since the stress is flow related and stress detection by shear responsive genes needs verification, the flow is also measured directly, in vivo, using micro PIV [3] and by measuring PV loops [2]. In the early stages the embryonic heart has a relatively simple form, namely a tube in the form of a deformed U where flow enters at one leg and leaves at the other. It is simple enough to be simulated numerically. The numerical model uses commercial CFD (Computational Fluid Dynamics) software and in-house codes based on the method of Peskin [4]. The codes are used for mutual validation, especially for the wall shear stress, and comparison with the experiments.
Although some places of high shear stress have been identified, other places need more investigation. For instance, the exact mode of beating of the heart may play a role, which changes from peristaltic to beating in the cause of time. Results shown at the conference will be a comparison of PIV flow measurements, shear stress responsive gene expressions and CFD models with respect to flow field and shear stress.

References

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4933 Th, 14:15-14:30 (P44)

Multiscale modelling of cardiac mechanics

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Driven by the need for a more anatomically realistic ventricular model and with access to greater computational power the Auckland porcine ventricular model [1] has been re-engineered based on the original experimental data. With increased finite element mesh resolution the new model includes the papillary muscles, addressing the main shortcoming of the previous model [2]. The model retains an accurate representation of the ventricular geometry including the apex and valve rings and also the underlying tissue microstructure [1]. A computational modelling and simulation framework developed for studies of cardiac electromechanics [3] is used to embed biophysically detailed models of cellular mechanics in the large scale anatomical model. This enables the integrative investigation of feedback mechanisms between the structure and function at the cellular and tissue scales with the macroscopic factors that govern the mechanical beating of the heart. The simulation framework combined