O6: Red blood cell Aggregation

O6-1 Alterations in RBC aggregation during incubation in glucose solution

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The abnormally elevated blood glucose level may results in cardiovascular disease, what can occur in patients with diabetes. Thus, precise determination of changes in hemorheology can be helpful in the diagnosis of the disease and monitoring its course. The alterations in RBC aggregation cause the changes in hemorheology. The change of the RBC aggregation in the presence of elevated glucose can be observed both in vivo and in vitro. To show the alterations we have determined the effect of different concentration of glucose on the process of RBC aggregation during in vitro incubation. For this purpose, RBCs suspensions with hematocrit 40% were investigated in autologous plasma with the addition of glucose at a concentration of 1 to 3 g/dL. The direct effect of the incubation of erythrocytes on the aggregation process was observed in Couette system during one or two hours, starting immediately after preparation of the sample. The rotation of inner cylinder of Couette system causes disaggregation of the cells. After cessation of the rotation of the RBC aggregation develops what is manifested by decrease in the intensity of the backscattered light. The following sequence of rotations was used: two minutes rotation is followed by two minutes stop and in this way we have obtained a time series of back scattered intensity. From the time series we have obtained individual syllectograms responsible for a given time of incubation. From the syllectograms we have obtained the time T_{slow} and T_{fast} describing RBC aggregation. It is shown that both T_{slow} as well T_{fast} change with the time of incubation and glucose concentration. As a result, alterations in the process of RBCs aggregation during incubation in glucose solutions were described.

O6-2 Numerical study of red blood cell aggregation kinetics under sinusoidal pulsatile flow

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Previous numerical modelling studies of red blood cell (RBC) aggregation elucidated the inverse relationship between shear rate and RBC aggregation under steady flow. However, information on RBC aggregation under pulsatile flow remains lacking. In this study, RBC aggregation was numerically simulated to investigate the complex interactions among RBCs under pulsatile flow.

RBCs were driven by hydrodynamic force, aggregation force, and elastic force under sinusoidal pulsatile flow in a two-dimensional particle model. The RBC aggregation kinetics were simulated based on the depletion model, and analyzed by averaged values from five cycles. We calculated the number of aggregated RBCs in the different regions with similar acceleration levels to observe aggregated RBC variation in the pulsatile flow.

The simulation results are in agreement with the previous experimental results for the formation and destruction of RBC aggregates with a parabolic radial distribution during a pulsatile cycle. In addition, the results demonstrated that the cyclic variation in the mean

aggregate size of RBCs increased as velocity amplitude increased from 1 cm/s to 3 cm/s, as mean steady flow velocity decreased from 6 cm/s to 2 cm/s, and as stroke rate decreased from 180 beats per minute (bpm) to 60 bpm. As anticipated, the computational results demonstrated that the number of aggregated RBC decreased exponentially with shear rate under sinusoidal pulsatile flow. The maximum RBC aggregation occurred at the acceleration region of about $2cm/s^2$. The simulation results verified the previous experimental results of parabolic radial distribution and improved the current understanding of the complex spatiotemporal changes of RBC aggregates during a sinusoidal pulsatile cycle.

O6-3 Structure and stability of red blood cell aggregates in model flows

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RBC is a strong determinant of blood rheology at low to moderate shear rates and influences the structure of blood flow in capillary networks. The stability of RBC aggregates or rouleaux is governed by many parameters which include fibrinogen concentration (or other aggregation promoter) and red blood cell properties which can vary with the age of RBCs or pathological situations. Through experimental and numerical approaches, we investigated the shape of RBC aggregates, revealing a large variety of shapes of contact zones between cells, which involve a buckling instability of membranes resulting from a competition between adhesion energy and membrane elasticity. The attractive interaction between cells also leads to clustering (rouleau formation) in flow, with a cluster size that is governed by a competition between hydrodynamic stresses and aggregation forces. We show that hydrodynamic stresses in the bifurcations of a capillary network can lead to rupture of clusters at a critical speed which is in the range of physiological values, and increases with interaction energy. Overall, the clustering phenomenon tends to increase phase separation and hematocrit heterogeneities in the microcirculation.

O6-4 Covalent immobilization of biomolecules on stent materials through mussel adhesive protein coating to promote cell adhesion

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It is widely accepted that surface biofunctional modification may be an effective approach to improve biocompatibility and confer new bioactive properties on biomaterials, especilly promote cell adhesion and viability. In this work, mussel adhesive protein (MAP) was applied as a coating on 316L stainless steel substrates (316L SS) and stents, and then either immobilized VEGF or CD34 antibody were added to create a promoting cell adhesion and viability films. The properties of the MAP coating were characterized by scanning electron microscope (SEM), atomic force microscope (AFM) and water contact angle test. Universal tensile testing showed that the MAP coating has adequate adhesion strength on a 316L stainless steel material surface. Subsequent cytotoxicity and hemolysis rate tests showed that

the MAP coatings have good biocompatibility. Moreover, using N-(3-Dimethylaminopropyl)-N`-ethylcarbodiimide hydrochloride and N-hydroxysulfosussinimide (EDC/NHS) chemistry, VEGF and CD34 antibody were immobilized on the MAP coatings. The amount and immobilized yield of VEGF on the MAP coatings were analyzed by enzyme-linked immuno-assays (ELISA). Finally, an endothelial cells culture showed that the VEGF biofunctional film can promote the adhesion, viability and proliferation of endothelial cells. An in vitro $CD34^+$ cells capturing test also verified that the film can capture $CD34^+$ cells and promote cell adhesion. These results showed that the MAP coatings allowed effective biomolecules immobilization. After biomolecules immobilization, the biofunctional film can promote cell adhesion and viability, which providing a promising platform for vascular device modification.

O6-5 The changes of vascular mechanical properties of porcine coronary artery after stent implantation

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Background and Aims: In-stent restenosis seriously affects the postoperative efficacy of percutaneous coronary intervention. The vascular cells could receive the stimuli of vascular mechanical environment changes during restenosis. At present, numerical simulation is often used to study the changes in mechanical properties of coronary arteries after stent implantation which still had disparity with actual data. This study aims to reveal the mechanical properties of coronary artery after stent implantation.
Methods: Bose mechanical tensile test system was used to test the uniaxial tensile stress and strain, relaxation mechanics of artery samples. And using balloon dilation instead of stent implantation to detect the changes in the opening angle of the stent after implantation.
Results: The stress strain curves were plotted through the results of the vascular multirate uniaxial tensile test, and the stent implantation could lead to the decrease of the viscoelasticity of the blood vessels. According to the results of relaxation experiment, the stress relaxation of stent implantation segment decreased sharply with the increase of time, unlike the normal vascular being stable after decreasing. The opening angle of the vessel without balloon dilation was changed with vessel position, farther away from the heart, the smaller the opening angle was. While the opening angle of the vessel with balloon dilatation was larger and had no difference between the proximal and distal segment.
Conclusions: The viscoelasticity, shear stress and opening angle of coronary arteries were significantly changed after stent implantation.
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