OPTICAL STUDY OF THE EFFECT OF DIABETES MELLITUS ON MICRORHEOLOGICAL PROPERTIES OF BLOOD


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Diabetes mellitus

Diabetes is a group of metabolic diseases, characterized by high blood sugar level in the blood of patients, because the pancreas does not produce enough insulin (insulin-dependent diabetes mellitus, abbreviated IDDM), or because cells do not respond to the insulin that is produced (non-insulin-dependent diabetes mellitus, abbreviated NIDDM).
Diabetes mellitus is a systemic disease that is becoming a higher and higher social problem due to the quickly growing number of population suffering from it. It induces severe alterations of vitally important organs of the human organism including the cardiovascular system.

An estimated number of 382 million people have diabetes worldwide

In 2012 diabetes resulted in 1.5 million deaths worldwide
Prevalence of Diabetes Mellitus worldwide

Concomitant diseases and complications

Diabetes without proper treatments can cause many complications:

- hypoglycemia
- coma
- chronic renal failure
- diabetic retinopathy (retinal damage)
- concomitant arterial hypertension

The major long-term diabetes complications are related to the damage to blood vessels and capillaries and impairment of blood rheological properties and lead to doubling the risk of cardiovascular diseases.

Control and monitoring of diabetic complications is very important. Thus, it is necessary to control the parameters of the blood flow (during diabetes diagnostics and treatment), in particular microrheological and rheological parameters.
Parameter that affect the blood flow

The rheological parameters are mostly related to the deformability and aggregation properties of red blood cells, which are expected to be impaired in diabetic patients.

- Deformability of RBCs
- Aggregation of RBCs
Deformability of RBCs

Deformation of RBC passing through capillaries with diameter equal and less then diameter of the capillaries.

RBC in dilute suspension under shear flow. Shear-induced elongation of RBC.

RBC deformation characterize the ability of RBCs to change their shape. This is one of key the factors in determining blood flow.
Aggregation of RBCs

Linear aggregates (Rouleaux)  3D - aggregates (network)

RBC aggregation is one of key the factors in determining blood flow resistance in microcirculation.
Aim of the work

To estimate of alterations the ability of human and rat erythrocytes to deform and aggregate in blood flow in case of Diabetes mellitus (DM)
Schematic layout of laser diffractometer

1 - laser, 2 - Couette chamber, 3 - mirror, 4 - step motor, 5 – CCD camera, 6 - PC, 7 – focusing lens.
Shear-induced deformation of RBC in Couette flow


Shear rate in Couette chamber:
\[ \dot{\gamma} = \frac{dV}{dz} = \frac{2\pi RN}{d} = \text{const} \]

Shear stress in the Couette chamber:
\[ \tau = \eta \dot{\gamma} \neq f(z) \]

where \( \eta \) - viscosity of the erythrocyte suspension
Laser beam diffraction scheme on a stationary suspension of RBCs

\[ \lambda = 633 \text{ nm} \]

- He-Ne laser beam
- Red blood cells
- Screen
Laser beam diffraction scheme on a suspension of RBCs in shear flow

Shear Flow

\[ \lambda = 633 \text{ nm} \]

Laser Beam

Red Blood Cells

Observation screen
Deformability index (DI) of RBC’s

RBC deformability index: \( DI = \frac{a - b}{a + b} \)

Typical diffraction patterns from suspensions of round-shaped and shear-elongated RBC
Schematic layout of laser aggregometry

1 - laser, 2 – photodetector, 3 - Couette chamber, 4 - step motor, 5 - PC

Aggregation kinetics on whole blood probe at stasis:

\[ I_a = C_1 e^{-t/T_1} + C_2 e^{-t/T_2} + C_3, \]

where \( I_a \) – intensity of backscattered light, \( T_1, T_2 \) – characteristic times of linear and 3D-dimension aggregates formation, \( t \) – time, \( C_1, C_2, C_3 \) – constants.

Disaggregation kinetics in whole blood probe under shear flow:

\[ I_a = C_4 e^{-\dot{\gamma}/\beta_1} + C_5 e^{-\dot{\gamma}/\beta_2} + C_6, \]

where \( I_a \) – intensity of backscattered light, \( \beta_1, \beta_2 \) – hydrodynamic straight coefficients of linear and 3D-dimension aggregates, \( \dot{\gamma} \) – shear rate, \( C_4, C_5, C_6 \) – constants.
Commercial available devices for measurements

- Laser diffractometer and aggregometer – LADE (RheoMedLab, Russia)
- Rheoscan (Rheomeditech, Korea)
Photo of laser diffractometer and aggregometer (LADE)
Rheoscan uses disposable plastic microchip including micro-stirrer
Results
Deformability Index dependence on shear stress for human RBC obtained with LADE
Deformability Index dependence on shear rate for rats RBC obtained with LADE

Shear stress, Pa

Deformability index

- Control group
- Diabetes
- Diabetes + hypertension
Characteristic time of 3D-dimension aggregates formation for rats RBCs obtained with LADE

- Control group: $N = 8$
- Rats with diabetes mellitus: $N = 7$
- Rats with hypertension and diabetes mellitus: $N = 7$
Characteristic time of 3D-dimension aggregates formation for human RBCs obtained with LADE

N = 12
N = 23
Characteristic time of aggregates formation for rats RBCs obtained with Rheoscan

![Graph showing characteristic time of aggregates formation for different groups with different sample sizes.](image-url)
Conclusion

- Laser diffractometry and aggregometry are easy and fast techniques for monitoring microrheology alterations.

- Deformability of RBC is impaired in case of diabetes.

- Diabetes mellitus leads to the reduction of the characteristic times of RBCs aggregates formation and as a result to higher resistance to the blood flow due to increasing the viscosity.

- Monitoring the deformability and aggregation of RBC in diabetic patients is necessary for controlling the efficiency of treatment and prognosis of complications.
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Thank You for your attention

??? Questions ???
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