Multiphysical Simulation of Vascular Streaming Potential and Verification

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ABSTRACT

The zeta potential of intravascular blood is a factor affecting blood circulation in association with blood coagulation. Therefore, researches and technological developments are being carried out to improve blood circulation through changes in zeta potential. In addition, the zeta potential is predictable through the streaming potential caused by the movement of blood. Blood in the blood vessels causes a streaming potential due to movement of the heart and it has transient characteristics. In this study, to develop a multiphysical simulation model for predicting the transient streaming potential signal, the theoretical solution of the transient streaming potential was derived and experimentally verified. In this study, multiphysical simulation model was developed and experimental verification was performed. In addition, a new analytical technique for analysing the strain generated electric potential of intravascular blood was studied. Experiments were performed to measure the blood streaming potential of experimental animals.

Theoretical solution of transient streaming potential was derived to perform multiphysical simulation to identify and predict the transient streaming potential of blood in blood vessels. In addition, numerical analysis and experimental verification of the transient streaming potential were carried out to analyze the transient density distribution of intravascular blood, and a multiphysical simulation model of the streaming potential was developed to quantify the characteristics of the streaming potential. The streaming potential of blood vessels with transient characteristics was solved based on the Debye-Falkenhagen equation, which is determined by diffusion coefficient, ion charge density, and inverse Debye length. In this study, a modified Debye-Falkenhagen equation is presented, which takes into account the effects of external electric fields in the body (Eq.1).

$$\frac{1}{D}\frac{\partial \rho_f}{\partial t} = \frac{\partial^2 \rho_f}{\partial y^2} - \kappa^2 \rho_f + \kappa^2 \varepsilon_f \frac{\partial^2 \phi}{\partial y^2} \qquad (Eq.1)$$

The quantification of the transient streaming potential was performed by a finite difference method based on the modified Debye-Falkenhagen equation (Eq.1) presented in this study. A multiphysical simulation model was developed to predict the transient streaming potential of blood. And, a method for predicting the zeta potential of blood using the values obtained through the experiment to measure the streaming potential of the experimental animals and the blood characteristics of the experimental animals was proposed.

Based on the multiphysical simulation model of blood vessels developed in this study, it is possible to predict the blood streaming potential and based on the results of the new analytical method, which quantifies the characteristics of transient streaming potential, it is expected to be used as an index of applied research on cardiovascular field using zeta potential. In addition, it is expected to be applicable to the development of application technology for medical devices, such as intuitive observation of blood vessels by measuring the streaming potential in the field of surgical operation in which blood vessels are operated.

REFERENCES

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