Transport of Macromolecules through Glomerular Capillary Wall
Numpong Punyaratabandhu1 and Panadda Dechadilok1,*

1Department of Physics, Chulalongkorn University, Bangkok, 10330 Thailand
*Corresponding author. E-mail: panadda.D@chula.ac.th

ABSTRACT

The main function of human kidneys is to filter blood and remove metabolic waste while retaining the normal blood composition and volume. The first step of this process is blood filtration through the glomerular capillary wall, which consists of multiple layers: endothelial cell layer, the glomerular basement membrane (GBM) and the epithelial foot processes with their interconnecting slit diaphragm.

A hydrodynamic model is introduced to describe hindered transport of electrically neutral macromolecules through the slit diaphragm and the glomerular basement membrane (GBM). The glomerular basement membrane is modeled as an isotropic fibrous medium, whereas the epithelial slit is modeled as a row of parallel cylindrical fibers, and the dimensionless flow resistance is calculated using finite element method. The non-uniform cylinder spacing is assumed to follow the gamma distribution. The averaged sieving coefficient is calculated by using those distribution functions and is compared with the total sieving coefficient of ficoll from experiments.

Acknowledgments

This work was financially supported by His Royal Highness Crown Prince Maha Vajiralongkorn Fund and the Thai Research Fund.

REFERENCES


CONCLUSION

The layer in glomerular capillary wall that plays the most crucial role in restricting transport of ficoll is the slit diaphragm, although the significance of the absence of slit diaphragm varies from 40% (in rats) and 60% (in humans) for small molecules to two and three order of magnitudes differences for larger molecules.

Keywords: Renal Transport, Diffusion, Convection, Glomerular Capillary Wall

INTRODUCTION

It is generally believed that the first stage of renal blood filtration occurs at the glomerular capillary wall in the glomerulus (Fig. 1): a capillary wall with its own unique nanostructure. Excess fluid, proteins and metabolic waste are transported from blood stream in the capillary lumen through the three layers into the primary urine in Bowman’s capsule. Abnormalities in glomerular capillary wall cause renal diseases. It is desired to relate measurable quantities such as sieving coefficient to structure of each layer.

OVERALL SIEVING COEFFICIENT

The sieving coefficient is the ratio between the downstream and upstream solute concentration (the concentration in blood stream and that in the primary urine). This project focuses on transport of uncharged rigid spherical solutes such as ficolls.

MODEL FOR GBM

GBM is a hydrogel with 95% in volume fraction being water and 10% being cross-linked fibers consisting of type IV collagen (r = 3.5 nm) and GAG (r = 0.5 nm). It is modeled as an isotropic fibrous medium, the solute concentration is governed by

\[ \frac{dC}{dx} = -K_x \frac{C}{\bar{x}_x} - K_y \frac{C}{\bar{x}_y} = 0 \]

where \( K_x \) and \( K_y \) are the diffusive and convective hindrance factors in the GBM.

RESULTS

Calculated total sieving coefficients are compared with experimental data from cooled isolated perfused kidney of Wistar rats and urinary analysis result in humans (1).

CONCLUSION

The layer in glomerular capillary wall that plays the most crucial role in restricting transport of ficoll is the slit diaphragm, although the significance of the absence of slit diaphragm varies from 40% (in rats) and 60% (in humans) for small molecules to two and three order of magnitudes differences for larger molecules.

ACKNOWLEDGMENT

This work was financially supported by His Royal Highness Crown Prince Maha Vajiralongkorn Fund and the Thai Research Fund.