WATER PERMEABLE NANOPOROUS MEMBRANE FOR IMPLANTABLE HEMODIALYSIS DEVICE
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ABSTRACT
This paper experimentally characterized water permeable nanoporous membranes for hemodialysis applications both in vitro and in vivo. We developed water-permeable and robust nanoporous membrane from a casting solution of polyether sulfone (PES), polyethylene glycol (PEG), and Dimethylacetamide (DMAc). In vitro tests verified that the membrane had higher water permeability than prior work and did not cause any leakage. Then, a hemodialysis device equipped with the developed membranes were connected to rat artery and vein and its permeability characteristics were evaluated. Aqueous filtrate was successfully collected, whose amount was affected by the blood pressure.

KEYWORDS: Hemodialysis system, Water permeability, Poly-ether-sulfone, Membrane

INTRODUCTION
Hemodialysis therapy is essential for patients who have end-stage renal disease, but frequent hospital visits, three times x 4 h a week, and rather acute treatment deteriorate the quality of life (QoL) of the patients. Implantable dialysis system will drastically improve their QoL, which requires a sufficiently small and no-dialysate dialysis device [1]. In the no-dialysate device, wastes (low-molecular-weight electrolytes) in blood are removed as solutes of aqueous filtrate, as shown in Figure 1. Therefore, the membrane mandates to possess water permeability. In addition, in prior work, leakage of blood due to rapture of the membranes often took place. The membrane needs to be strong enough to survive blood pressure that fluctuates with a heartbeat.

THEORY
The amount of filtrate \( \Delta q \) through the membrane is defined as the following;

\[
\Delta q = P_w \cdot S \cdot \frac{1}{t} \cdot \frac{1}{2} \rho v^2
\]  

(1)

where \( P_w \) is the water permeability \([m^3 \cdot s/kg]\), \( S \) the membrane area \([m^2]\), \( t \) the thickness of membrane\([m]\), \( \rho \) the density of blood \([kg/m^3]\) and \( v \) the velocity of liquid \([m/s]\). Therefore we can obtain water permeability \( P_w \) according to the equation (2).

\[
P_w = \frac{2\Delta q \cdot t}{\rho S v^2}
\]  

(2)

Figure 1. Concept of Implantable Hemodialysis Device without dialysate
Table 1. Mixing ratio of PES/PVP/NMP, PES/PEG/DMAc and their structure

<table>
<thead>
<tr>
<th></th>
<th>PES</th>
<th>PVP</th>
<th>NMP</th>
<th>Solvent PES</th>
<th>Solvent PVP</th>
<th>Solvent DMAc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.0</td>
<td>10.0</td>
<td>80.0</td>
<td>MW: 4800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>15.0</td>
<td>15.0</td>
<td>70.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>20.0</td>
<td>20.0</td>
<td>60.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXPERIMENTAL

In this work, as shown in Table 1, we formed a membrane using PES, PEG, and DMAc. The ratio of PES in the casting solution was found to determine the robustness of the membrane.

A cow whole blood was flowed at the rate of 100 μl/min into the one-layered device in in vitro tests, as shown in Figure 2.

Figure 3 showed setup of in vivo test. The dialysis device that stacked 11 micro-channel layers and 10 membranes (14.1% PES, 11.8%PEG, 74.1% DMAc) was connected to a chronic renal failure rat. The artery and vein are connected to the inlet and outlet of the device. The blood pressure was monitored during the experiment. Then, 5ml saline was added from another vein to the rat for 2 min to rise the blood pressure.

RESULTS AND DISCUSSION

The newly developed composition achieved high water permeability even with a high ratio of PES in in vitro experiments, as shown in Figure 4.
Figure 5 showed result of *in vivo* experiment. No leakage was observed and the filtrate was successfully collected. The filtrate amount was above the target value of 0.2 ml, which was set by a medical doctor. The filtrate was found to increase after the addition of saline, which implies that the filtrate amount depend on the blood pressure. We also investigated the composition of blood before and after the device. The concentration of potassium decreased while that of albumin was maintained. This indicates that the membranes allowed only low-molecular-weight molecules to permeate through, which satisfies the requirements for the dialysis membranes.

**CONCLUSION**

*In vitro* tests verified that the membrane had higher water permeability than prior work and did not cause any leakage. *In vivo* experiment verified that the developed membranes are readily applicable for the membranes of the implantable hemodialysis system.

**REFERENCES**


**CONTACT**

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