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Polymeric Membrane Materials for Artificial Organs

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Abstract: ***Many polymeric materials have already been used in the field of artificial organs. However, the materials used in artificial organs are not necessarily created with the best material selectivity and materials design; therefore, the development of synthesized polymeric membrane materials for artificial organs based on well-defined designs is required. The approaches to the development of biocompatible polymeric materials fall into three categories: 1. control of physicochemical characteristics on material surfaces, 2. modification of material surfaces using biomolecules, and 3. construction of biomimetic membrane surfaces. This review will describe current issues regarding polymeric membrane materials for use in artificial organs. Biomolecular response to polymeric materials It is well known that when synthetic polymers contact the tissues and blood of living organisms and the body of the organism recognizes the polymeric materials as foreign substances, thrombus formation, the immune reaction and the inflammatory reaction will be triggered. Thrombus formation is a complex cascade reaction in which various components in blood perform their role: the major factors of thrombus formation include insoluble fibrin production by various plasma protein-based cascade reactions of coagulation factors, white thrombus formation by coagulation of platelets and acceleration of white blood cell adherence.***

Keywords: Polymeric membrane materials, Biocompatibility, Medical device, Nanomaterials

1. Introduction

In the field of artificial organs, many polymeric materials have already been used, e.g., artificial hearts designed using polyurethane, artificial kidneys using cellulose and polysulfide, and membrane oxygenators with porous polypropylene. However, the polymeric materials used in the previous artificial organs were not created with the best material selectivity and materials design. They have come to be used through improvements in existing polymeric materials for use in artificial organs. Therefore, the development of synthesized polymeric materials for artificial organs based on well-defined design guidelines will be essential in the future. Furthermore, the innovations represented by nanotechnology in recent years have had a great impact on the field of artificial organs. The immune reaction is a biological reaction in which the body of a living organism recognizes pathogens and foreign substances and tries to eliminate them. White blood cells play a central role in the immune reaction. In addition, other types of cells send signals to lymphocytes, and macrophages react to the cytokines released from such cells. Since many polymeric membrane materials used in artificial organs contact constituents of blood directly, the materials must be biocompatible and able to avoid causing thrombus formation, the immune reaction, and the inflammatory reaction mentioned above. Inhibition of the adsorption of proteins onto the surface of the materials is important because it is known that the biological reactions mentioned above are triggered by protein adsorption. Now, many polymeric materials being developed as biocompatible materials are required to inhibit adsorption of plasma proteins.

2. Materials and Methods

As mentioned above, the major factors in the reaction of thrombus formation are the generation of insoluble fibrin by the cascade reaction of coagulation factors and the generation of white thrombus by aggregation of platelets; however, for thrombus formation on polymer surfaces, platelet adhesion on the surface plays a particularly important role. It is known that the adsorption of plasma proteins, such as albumin, immunoglobulin, and especially fibrinogen, contribute to platelet activation and aggregation. Thus, polymer surfaces that can reduce the adsorption of fibrinogen are considered to exhibit at least blood compatibility. Another important issue is how to inhibit the activation of complements, which are directly and indirectly, involved the in immune reaction and the inflammatory reaction. The activating pathways are divided into the classical pathway and the alternative pathway. In the classical pathway, complements are activated by formation of immunoglobulin and the C1q complex; in the alternative pathway, complements are activated by the binding of C3b to surfaces with hydroxyl groups.7 Polymeric materials with hydroxyl groups on their surfaces facilitate activation of complements. A typical polymer used for membrane materials in artificial organs is Polydimethylsiloxane (PDMS). Because PDMS has a hydrophobic surface and a low surface free energy and may suppress the adsorption of biogenic substances, it has been clinically applied for many medical treatment devices, such as membrane oxygenators. Aromatic polysulfones are also employed as hemodialysis membranes because of their similar surface properties. Polysulfide membrane has excellent performance, e.g., it inhibits activation of complements and has improved filtration efficiency, when compared with conventional cellulose dialysis membrane.

Polymeric Membranes for Artificial Lungs

Artificial membrane lungs are devices that perfuse circulating blood by membrane transport of gases. The development of membrane lungs was prompted by a need for an efficient device that could be used longer and that would damage the blood less than the direct blood-gas contact oxygenators. In most commercial membrane artificial lungs, the most significant resistant to gas-transfer is the laminar boundary layer of blood near the membrane.

Artificial lungs designed to improve the efficiency of gas transfer per unit area of membrane by minimizing the effect of the stagnant blood boundary layer are now available.

Membrane surface properties can be tailored in the case of polydimethylsiloxane, polysulfone (hydrophobic surface), polyethylene oxide, polyvinyl alcohol (hydrophilic surface), or hybrid membranes by microphasic separation. Surface functionalization of membranes with biomolecules is performed using biological species that usually have some of the specific functions of an organ (e.g., heparin which inhibits internal coagulation or urokinase for kidney function).

3. Conclusion

The approaches to the development of Biocompatible polymeric materials fall into three categories: (1) Control of physicochemical characteristics on material surfaces, (2) modification of material surfaces using Biomolecules, and (3) Construction of Biomimetic membrane surfaces Phospholipid polymer. Biomedical polymers have the basic design of synthetic polymer but they also have the nature of hydrophobic surface & Biocompatible. Due to their Biocompatible nature polymeric membrane materials used in artificial organs will contact the constituents of blood directly and able to avoid causing thrombus formation, the immune reaction, and the inflammatory reactions.

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