THE INFLUENCE OF SURFACE PROPERTIES OF NANOCOMPOSITE MEMBRANES ON DIALYSIS PERFORMANCE

Dominika Wójtowicz (1,2), Anna Ścisłowska-Czarnecka (3), Ewa Stodolak-Zych (1)

1. Department of Biomaterials and Composites, Faculty of Materials Science and Ceramics, AGH University of Krakow, al. Mickiewicza 30, 30-059 Krakow, Poland; 2. Clinical Department of Anaesthesiology and Intensive Care, University Hospital in Krakow, ul. Jakubowskiego 2, 30-688 Krakow, Poland; 3. Faculty of Motor Rehabilitation, Bronislaw Czech University of Physical Education in Krakow, Al. Jana Pawła II 78, 31-571 Kraków, Poland

Introduction

Protein adsorption on biomaterials in contact with blood is a significant challenge during renal replacement therapy (RRT) which results in the activation of interrelated pathways, leading to the thrombosis and activation of the immune system (Fig. 1). Determinant for occurrence of fouling are the interactions between a membrane and the charged protein. Understanding the effect of the protein adsorption on solid surfaces is crucial for engineering membranes with enhanced performance parameters and prolonged lifespan [1].

In this study, polysulfone membranes were modified by incorporation of different carbon nanoforms during manufacturing process to alter the surface characteristics to reduce protein fouling without decreasing the dialysis membranes biocompatibility.

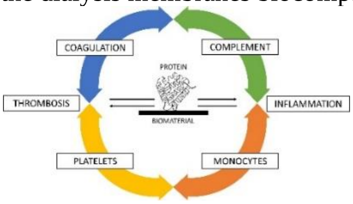


Figure 1: Pathways activated as a response to a contact of biomaterial with blood.

Methods

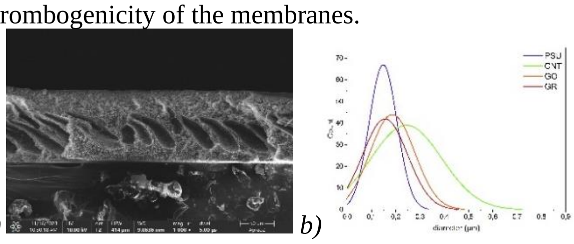
Three nanocomposite polysulfone-based membranes (PSU, Sigma-Aldrich) were manufactured by the liquid-induced phase separation without solvent method using dimethylformamide (DMF, Avantor SA) as the solvent, and water as the non-solvent. As a filler were used different carbon nanoforms: 2%wt. carbon nanotubes (CNT, Nanostructured & Amorphous Materials), 1%wt. graphene oxide (GO, NanoAmor US) and 5%wt. graphite (GR, NanoAmor US).

The membranes microstructure was assessed by the scanning electron microscopy (SEM, Apreo 2) with a subsequent image analysis (ImageJ) to obtain data about their thickness, porosity and pore size distribution. A surface zeta potential (charge) analysis was conducted using Zetasizer (Malvern) and contact angle and surface free energy were determined with DSA25E goniometer (Krüss). Permeability tests were performed on a dialyzer of the own construction to determine the molecular weight cut-off (MWCO) and the pure water flux. Compatibility with biological systems was tested with macrophages and fibroblasts cell cultures and assessed for thrombogenicity.

Results

The carbon nanoforms are present in both a skin and a support layer of asymmetric membranes (100 um thickness), which is proven by changes in Zeta potential. The modified membranes show finger-like pore structure in the support layer and unimodal distribution of pore size in the skin (Fig. 2) and similar skin-to-support ratio (1:3). All nanocomposite membranes have increased surface free energy (up to 50,52 mN/m for CNT) and hydrophobicity (CA from 89,9° to 109,2° for GR). Permeability of membrane by means of the water flux increased only in the case of the membrane modified with CNT. The other additives were less effective in the water flux test. Biocompatibility in *in vitro* tests revealed low cytotoxicity and thrombogenicity of the membranes.

a)



b)

Figure 2: a) CNT-modified membrane cross-section with skin and support layer b) pore size distribution in the skin layer.

Discussion

The membranes were characterized in terms of four aspects: morphology, surface properties, performance parameters and biocompatibility. In comparison with the pristine PSU membrane, the surface charge of the modified membranes decreases, increasing the magnitude of electrostatics repulsion between the surface and foulants, both charged negatively in a physiological pH of blood.

Conclusions

The obtained nanocomposite membranes can be an alternative to pure polymeric membranes. The presence of carbon nanoforms affects the surface properties by reducing protein fouling and coagulation.

References

1. Florens N, Guebre-Egziabher F, Juillard L. Reconsidering adsorption in hemodialysis: is it just an epiphenomenon? A narrative review. J Nephrol 2022; 35: 33–41.

Acknowledgements

This work was supported by “Initiative of Excellence – Research University” (IDUB) grant ID 4204.