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A novel approach for blood purification: Mixed-matrix membranes combining diffusion and adsorption in one step

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ABSTRACT

Hemodialysis is a commonly used blood purification technique in patients requiring kidney replacement therapy. Sorbents could increase uremic retention solute removal efficiency but, because of poor biocompatibility, their use is often limited to the treatment of patients with acute poisoning. This paper proposes a novel membrane concept for combining diffusion and adsorption of uremic retention solutes in one step: the so-called mixed-matrix membrane (MMM). In this concept, adsorptive particles are incorporated in a macro-porous membrane layer whereas an extra particle-free membrane layer is introduced on the blood-contacting side of the membrane to improve hemocompatibility and prevent particle release. These dual-layer mixed-matrix membranes have high clean-water permeance and high creatinine adsorption from creatinine model solutions. In human plasma, the removal of creatinine and of the protein-bound solute para-aminohippuric acid (PAH) by single and dual-layer membranes is in agreement with the removal achieved by the activated carbon particles alone, showing that under these experimental conditions the accessibility of the particles in the MMM is excellent. This study proves that the combination of diffusion and adsorption in a single step is possible and paves the way for the development of more efficient blood purification devices, excellently combining the advantages of both techniques.

1. Introduction

The prevalence of end-stage renal disease (ESRD) was ~535,000 in the USA in 2008. Of these patients, ~355,000 were treated with hemodialysis. Despite the high health care costs of dialysis treatment (over €50,000 per patient per year), hemodialysis is only partially successful in the treatment of patients with ESRD. Mortality (15–20% per year) and morbidity of these patients remain excessively high, whereas their quality of life is generally low [1]. This is reflected in the expected remaining life years, which are 25.0 years for the general US population, 15.7 for ESRD patients with a kidney transplant and 5.6 years for ESRD patients receiving dialysis treatment [2].

In the last three decades, sorbent technology has been applied in the treatment of severe intoxication and to increase the efficiency of hemodialysis, or replace it, and as a treatment for fulminant hepatic failure. In hemoperfusion (or plasma perfusion), blood (or plasma) is purified by extracorporeal passage through a column containing the adsorbent which can remove or neutralize the substance of interest. Hemoperfusion cannot fully substitute hemodialysis because it does not remove urea and excess fluid. Sorbents used in hemoperfusion help to remove uremic toxins; however, direct blood contact with the adsorbent often causes hemocompatibility issues, especially on the long term [3]. Activated carbon (AC) has a long record as a sorbent in blood purification in the case of intoxications, acute and chronic renal failure as well as liver failure [3–5]. Uncoated activated carbon is a strong adsorbent for uremic toxins [6] whereas polymeric coatings of activated carbon might

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