

# A Brief Presentation of the Characteristics of Hemodialysis Membranes

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*The survival of CKD patients has known significant improvement with the appearance of extrarenal clearance methods. Being a domain in a rapid progression, the hemodialysis membranes have been, in time, one of the key modifying points. In this paper will make a short presentation of the features of hemodialysis membranes and will point out aspects which need future research.*

*Keywords: hemodialysis, hemodialysis membranes, cellulose, polymers, inflammation*

In 1943 the dutch physicist Willem Kolff revolutionized Nephrology by building the first hemodialysis machine. The research this build was based on was an article belonging to the Johns Hopkins University. It contained principles of toxin clearance in animals. A next big step in the history of hemodialysis was the invention of a vascular access pathway for patients who required long term extrarenal clearance [1]. Because the survival of patients with irreversibly affected renal function requires multiple hemodialysis sessions, the research in this field was focused on building devices which were well tolerated by the human body and with good toxin clearance [2].

## Experimental part

In patients with severely altered renal function, usage of different types of hemodialysis membranes ensures the removal of toxins from the organism. These devices allow the extrarenal clearing of the blood based on the physical phenomena of diffusion, convection and absorption [2].

The molecules which are removed from the organism are classified by molecular mass as small molecules (mass below 500 Da); medium sized molecules (mass ranging from 500-15000 Da) and large molecules (mass greater than 15000 Da). Regarding clearance capacity, small molecules are filtered through diffusion, while large molecules require large-pore membranes (high flux membranes). High flux membranes also have the advantage of limiting large molecular mass protein loss,

such as albumin, and have a higher chronic hemodialysis session efficiency. (greater URR, Kt/V values compared to low flux membranes) [4,6].

The main toxin clearing mechanism is through diffusion and it is achieved by any hemodialysis membrane. Through this mechanism the solutes travel from one compartment to another, based on the concentration gradient of the two compartments [7].

Through convection, achieved by high flux dialysis machines, the low molecular mass proteins and the solutes are separated from the formed elements, limiting their loss. This process relies on porosity and the increase of the efficiency of molecule transfers [3,8].

Adsorption is the third mechanism through which the clearing of uremic toxins from the organism is made possible. It relies on the pores' structure and the hydrophobicity of the membrane [3,9].

Hemodialysis membranes were initially built from cellophane, later from cellulose and nowadays from synthetic materials (synthetic polymers) which have made significant progress in solute clearing capacity [10]. Hemodialysis membranes made from cellulose have a thickness ranging from 6.5-15 μm, being classified as thin hemodialysis membranes. To ensure solute diffusion, they have a uniform, symmetric fiber structure. Unlike them, the synthetic membranes have a thickness  $\geq 20 \mu\text{m}$  and their structure can be symmetric or asymmetric. Typical for the asymmetric membranes is that they are fabricated

Small molecular mass molecules (<500 Da)	Medium sized molecular mass molecules (500-15000 Da)	Large molecular mass molecules (>15000 Da)
Urea	Vitamin B12	Myoglobin
Creatinine	Insulin	Retinol-Binding Protein (RBP)
Phosphate	Endotoxin fragments	EPO
	PTH	Albumin
	$\beta$ 2-microglobulin	Transferrin

**Table 2**  
TYPES OF SOLUTES BY MOLECULAR MASS

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from synthetic polymers and its fibers are *curled up* [2] to facilitate a wider contact surface between it and the patient's blood. From specialized literature we have concluded that some synthetic membranes consist of a thin inner layer which is surrounded by a thick outer layer with supportive role, while other hemodialysis membranes consist of 3 types of layers, of which the outer one has a supportive role [3].

### Results and discussions

Different materials are used in the hemodialysis membrane fabrication process, such as polysulfone (PSF), polyethylenesulfone (PES), cellulose triacetate (CTA),

polymethacrylate (PMMA), vinyl alcohol-co-ethylene (EVAL), and polyacrylonitrile (PAN) [3].

Using synthetic membranes plays an important part in assuring increased biocompatibility, so that there are minimal rejection reactions from the organism. This suggests the fact that biocompatible membranes lead to a decreased inflammatory response from the body, which, when it appears due to low biocompatibility membrane usage, leads to either hemodynamic instability or amyloidosis. Also, high biocompatibility membranes decrease the morbidity and mortality of chronically hemodialyzed patients [11].

SYNTHETIC HEMODIALYSIS MEMBRANES	STRUCTURE	PRIMARY POLYMER/ OTHER POLYMERS	MECHANISM	CLINICAL BENEFIT
PSB MEMBRANES	Filed fibers	polysulfone- PSF- primary polymer/ Polyvinylpyrrolidone (PVP)- hydrophilization agent	Convection	
PES MEMBRANES	Advance filing process- larger, denser more uniform pores	polyethylenesulfone - PES/ Mix of basic hydrophobic polymers	Perm-high selectivity	Removes medium-sized molecules with minimal albumin loss
CTA MEMBRANES	Thin fibers, Moire structure	cellulose triacetate - CTA	High permeability	Can clear out $\beta$ 2-M (diffusion) High albumin adsorption, low coagulation cascade activation
PMMA MEMBRANES	Homogenous structure- the whole membrane contributes to adsorptive clearance	polymethacrylate - PMMA	High adsorptive capacity-sulfate , indoxysulfate and 4-methyl-5-propyl-2-fumarpropionyl (CMPF) acid reduction; intact PTH adsorption	Improvement of cardiovascular strain, of pruritus, maintaining muscle mass in the elderly (due to its high adsorption capacity)
PEPA MEMBRANES	3-layered structure; porous inner layer	polyethylenesulfone - PES and polyacrylate	Water and solute permeability is controlled by the membrane's layers	Minimal complement activation- Polyvinylpyrrolidone-free membrane (PVP )
EVAL MEMBRANES	Smooth surface, hydrophilic membranes	vinyl alcohol-co-ethylene polymers - EVAL	Low plasma protein absorption, weak interactions with formed elements	Minimal thrombocyte activation, low inflammatory cytokine production-useful in patients with vascular disease
PAN MEMBRANES	Hydrophilic membranes	polyacrylonitrile- PAN	High permeability for fluids and uremic toxins; Specific adsorption through Monocyte Chemoattractant Protein-1 (MCP-1) elimination	

**Table 1**  
CHARACTERISTICS  
OF SYNTHETIC  
HEMODIALYSIS  
MEMBRANES

The measuring of high serum inflammatory cytokine levels during the hemodialysis session has led to the hypothesis that the symptoms which appear at the chronically hemodialyzed patient are due to high levels of inflammation, which are specific for this type of patient [12].

The basis on which this occurs is mainly due to the interaction between the blood and the hemodialysis membrane [13].

The new membrane's biocompatibility refers to the decrease of the degree of inflammation during the hemodialysis session [2]. This can be noticed in polysulfone membranes as well as in newer synthetic membranes which are made from Helixone [14]. As well as greater biocompatibility, the newer membranes offer a more efficient uremic toxin clearance [6,13]. New synthetic membranes are used also in plastic surgery, for immediate-breast reconstruction [15], but also in general surgery to repair the abdominal wall defects [16].

An important feature of chronic inflammation in a chronically hemodialyzed patient is the production of a faulty, incomplete  $\gamma$ -IFN molecule. The use of new synthetic Helixone (high flux membranes) membranes led to an improvement in  $\gamma$ -IFN production, resembling normal production. According to specialized studies, these membranes did not substantially alter serum inflammatory marker levels, such as Il-6, CRP, Il-18 [17].

## Conclusions

In chronically hemodialyzed patients there is a tight relationship between chronic inflammation and survival. In this regard, for the increase of these patient's survival, more in vivo and in vitro studies are needed to create hemodialysis membranes which have a major impact in decreasing serum inflammatory marker levels [18].

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