Comparison of CTA and ATA membranes in hemodialysis – A review

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Abstract: Hemodialysis (HD) is a treatment to extend life in patients with advanced kidney failure which focuses on palliative care and helps in improving the quality of life. Added to the tedious procedure of HD, the membranes used and their properties play a critical role in blood purification by removal of uremic toxins. Under certain circumstances the activation of circulating mononuclear cells or complement system activation in blood may occur which can lead to severe patient outcomes including cardiovascular morbidities. This can be avoided by the use of a more biocompatible membranes. Cellulose based membranes are widely preferred for dialysis over a long period of time. Different studies on CTA membranes and their derivatives based on biocompatibility and membrane-induced adverse effects were conducted over the years and led to new advancements for a progressively successful therapy. This paper deals with the brief review on the study and applications of CTA membrane and its derivative ATA membrane in hemodialysis.

Keywords: ATA membranes, Diabetes Mellitus, On-line Hemodiafiltration, Polysulfone synthetic dialyzer membrane, Hypertension

INTRODUCTION

A healthy kidney works by eliminating wastes, filtering the blood and maintaining the body's electrolyte balance through a series of processes. However, when kidneys become nonfunctional, they must be either transplanted or dialysis is prescribed. Based on the characteristics of the membrane used, the therapy can turn out to be a success or may end in dismay. Though synthetic polysulfone dialysis membranes are considered to be very biocompatible they have the ability to reduce the platelet counts through platelet activation by unknown mechanisms and are cumbersome. Because of this, substitution with the next high biocompatible membrane i.e., cellulose triacetate membranes and their derivatives must be considered as they have an unreactive chemical composition and a very low propensity to activate platelets.

Cellulose Triacetate membrane: It presents a high solute permeability so that can remove β_2-microglobulin by diffusion. The efficiency in diffusion is very high as the fibers are thin and the structure results in a uniform dialysate flow distribution.[13]

ATA membranes are CTA membranes with asymmetric structure which were developed by spinning technology with tiny morphological differences (irregularities or roughness on the inner surface) in comparison with CTA membranes.

Comparative studies on CTA and ATA membranes

The studies based on the removal properties of ATA membrane in OL-HDF (On-line hemodiafiltration), revealed that the albumin leakage quantity was selectively suppressed with ATA membrane which might contribute to the safety of the treatment.[14]
This was supported by another recent study done in 10 isolated covid patients undergoing MHD (Maintenance Hemodialysis), in which they found out that the ATA membrane usage led to the reduction in the loss of albumin which is an added criteria to their original aim of minimizing the concentration of inflammatory cytokines which increased with other mediators such as CRP, Procalcitonin etc., during second wave of covid.
In uremic toxin removal studies both the CTA and ATA has same results but the asymmetric CTA membranes had achieved better results for large molecules.[1]

CTA membranes on the other hand are widely used to avoid membrane-induced adverse reactions and also for a proper sustainable treatment. This was evidenced by a study involving the comparison between CTA membrane and PAES: PVP membrane on the basis of complement activation which showed a decrease in complement activation with the use of CTA membrane.[1]

A recent study on finding the reduced rates of pancreatic hormones glucagon and insulin in patients undergoing HD was done using two different membranes CTA & PS (polysulfone membranes)

which revealed the reduced rates of both hormones were comparatively higher with the PS membrane than with the CTA membrane. This study has several limitations and hence, further investigation is required.[7]

A research team was set up with the motive of studying the biocompatibility of CTA membrane with ATA membrane. Before the study, out of several factors that are involved in the activation of platelets and initiation of coagulation cascade the hydrophobicity and roughness of the membrane surface were believed to have a considerable impact. Experimentally, not much difference was observed regarding these factors. But, in practical cases of dealing with dialysis patients the use of dialyzers with smooth surface led to a higher therapeutic benefit ratio in patients. Hence, CTA membrane may turn out to be more effective.

On investigation of three membranes cellulose triacetate (CTA), asymmetric CTA (termed ATA®), and polyether sulfone (PES) membranes for reinvention of a new membrane it was revealed that, the asymmetricity of the membrane (index for asymmetricity) is the highest in PES and the lowest in CTA. The highest values of IF (index of fouling) was shown by PES and ATA had highest solute permeability.

The morphology of the membranes when studied showed that CTA was a homogenous membrane and ATA and PES had asymmetric or heterogeneous.
However, further studies are necessary in relation to adsorption characteristics to employ these membranes for the development of a novel membrane. [8]

In some studies, the influence of cellulose triacetate (CTA) on platelet activation was compared with polysulfone (PS) membranes and the level bound GPIIb/IIIa was found to be higher in the polysulfone group.[12]

CASE STUDIES

A case of 82-year-old man with the history of chronic kidney disease who started renal replacement therapy with polysulfone dialysis membrane had normal platelet count on the day of admission (233× 10/L) which gradually decreased (37×103/L). The patient was diagnosed with dialysis-induced thrombocytopenia which was reversed by substitution with Cellentia-H cellulose triacetate single-use, hollow-fiber, high-flux hemodialyzer membrane.[3]

A 91-year-old American-African male was initiated with HD treatment using polysulfone membrane. After 2 sessions the platelet count reduced from 184,000 to 22,000. The suspicion of Heparin-induced thrombocytopenia was ruled out and the membrane was switched to alpha-polysulfone membrane. But the platelet count remained variably depressed. Finally, the membrane was switched to CTA after which the platelet counts of the patient started to improve.[6]

A 54-year-old female patient with ESRD was initiated with dialysis and the membrane used was polysulfone synthetic dialyzer membrane. Post dialysis platelet count dropped and all other clues for dialysis-related thrombocytopenia were ruled out. Gradual fall and rise in platelet counts were observed even after the second session. The third session was performed by replacing the membrane to modified cellulose triacetate membrane and the platelet count was found to be stable after the dialysis.[11]

Another case report of 80-year-old man, undergoing HD treatment with polyether sulfone membrane in the dialyzer. But the patient developed desaturation and excessive sweating at the beginning of each dialysis session which led to the suspicion on adverse reactions with the dialyzer so, it was switched to polysulfone and PVP membranes but the patient's condition remained unchanged. No eosinophilia, increased IgE or anti heparin antibodies were observed and the cultures of the dialysis fluid and endotoxins were negative. So, finally the synthetic membranes were replaced with the cellulose triacetate (CTA) dialyzer after which the patient was relieved from any of the above symptoms.[11]

A 63-year-old patient, Caucasien male, was prescribed with dialysis treatment. Synthetic non-cellulose polysulfone membrane was used but within few minutes into the dialysis session, the patient developed severe flushing of the face and chest, along with diaphoresis, tachycardia, desaturation, and generalized shaking. Type A hypersensitivity reaction to the dialyzer membrane was suspected and the dialysis treatment was immediately stopped and the patient was treated with intravenous antihistamines and steroids and was brought back to normal. Relevant laboratory values were normal. Next day, the patient was premedicated with antihistamines and steroids and the dialysis was prescribed with a substituted cellulose triacetate membrane. No further reactions were reported. Subsequent dialysis treatments were all accomplished.[10]

Potentials of ATA and CTA membranes in on-line hemodiafiltration

On-line hemodiafiltration (OL-HDF) it is now a days the mostly preferred dialysis technique which increase the survival rate. A total of 16 patients undergoing OL-HDF were measured for their serum levels of urea, creatinine, β2 microglobulin, myoglobin, prolactin, α1-microglobulin, α1-acid glycoprotein and albumin at the beginning and end of the sessions. Greater replacement value was obtained by asymmetrical CTA membranes compared to conventional CTA membranes. [9]

CONCLUSION

The ATA membranes have a good biocompatibility and inflammatory profiles on comparison with CTA membrane and hence can be considered a valid option for patients who are allergic to synthetic membranes. But, its effectiveness on dealing with hypersensitivity reactions still remains unexplored. But both the CTA and ATA membranes are more effective and biocompatible when compared to synthetic dialyzer membranes.

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