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Towards More Effective Dialysis Treatment in Patients with Chronic Kidney Disease: Hypothetical Model of Dialyzer with Double Capillary Walls

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Keywords

Plasma Dialysis, Chronic Renal Failure, Dialyzers, Novel Systems

Plasma dialysis, which involves separation of blood cells from the plasma before the dialyzer, allowing only for the passage of plasma through the dialyzer canal. The aim of this study was to suggest novel model of high efficacy plasma dialysis as hemodialysis alternative. Electron microscopy imaging of the capillary lumens following an investigation plasma dialysis and hemodialysis were performed. Full blood clearance index was calculated, basing on the percent reduction of creatinine level before and after the dialysis both for the typical hemodialysis and plasma dialysis. Visualization of the plasma dialysis procedure indication decrease in the number of attached blood cells of compared to the hemodialysis. Creatinine clearance index ranged 79-86% for the hemodialysis and decreased over time during the procedure, while for plasma dialysis ranged from 94 to 95%. Also, no decreasing trend in procedure efficacy over time was found. Based on the experimental data two models for dialyzers were designed: rotary dialyzer and dialyzer with double capillary walls. Plasma dialysis may allow for the improved plasma clearance with estimated about 20% higher efficacy compared to the hemodialysis based systems, be useful in the setting of relatively low blood flow (for example 100-150 ml/min) and may reduce duration and frequency of dialysis procedures.

Introduction

Currently it is clear that adequate degree of dialysis of patients with chronic renal failure not only prolongs their survival, but also results in reduction of atherosclerosis progression and improves their immunity against infections or malignancies, eventually resulting in reduction of treatment costs [1-3]. Therapy of such patients is multifactorial. Essentially it can be divided into medical treatment (maintenance and forcing residual urine output, using an optimal diet and fluid supply, treating an underlying disease, controlling potential infection foci, treating abnormalities of erythropoesis, lipid metabolism, calcium-phosphate) and procedural treatment (renal replacement therapy) [4]. Improved degree of dialysis in these patients during repeated hemodialysis can be achieved by, among others: increased duration and frequency of dialysis procedures, increased blood flow through the blood channel in the dialyzer to a maximum value, increased flow of the dialyzing fluid, use of dialyzers with large exchange areas, dialysis through two-needle access, alternating hemodialysis and hemodiafiltration procedures [5, 6].

However, all these methods are not universally effective, in particular in patients with poor vascular access (with low efficiency) or those who poorly tolerate increased dialysis duration or frequency [7-11]. In such cases the treatment of choice may involve plasmadialysis as suggested in this study. Plasmadialysis is based on the principle of removing the plasma and passing through the extracorporeal medical device for the purpose of separation of the cellular components from the blood [12].

After separation, cellular components are re-infused to the system. It is also effective in removal of soluble immune complexes, modulate humoral response and decrease the titers of the autoantibodies, inflammatory modulators providing beneficial effect on the endothelial function and immune regulation [13]. Its most common uses so far have included anti-GBM nephritis, cryoglobulinemia, or hemolytic-uremic syndrome, where removal of the circulating toxic factors is essential [14].

Here, we wish to present the concept of solution based on an assumption that diffusion of toxic compounds from the full blood to the dialyzing fluid may be hindered by the presence of blood cells that adhere to pores in the dialyzing membrane and impair the above mentioned process (Fig. 1). The aim of this study is to propose the new model of plasmadylisis and compare its efficacy to the conventional hemodialysis procedure.

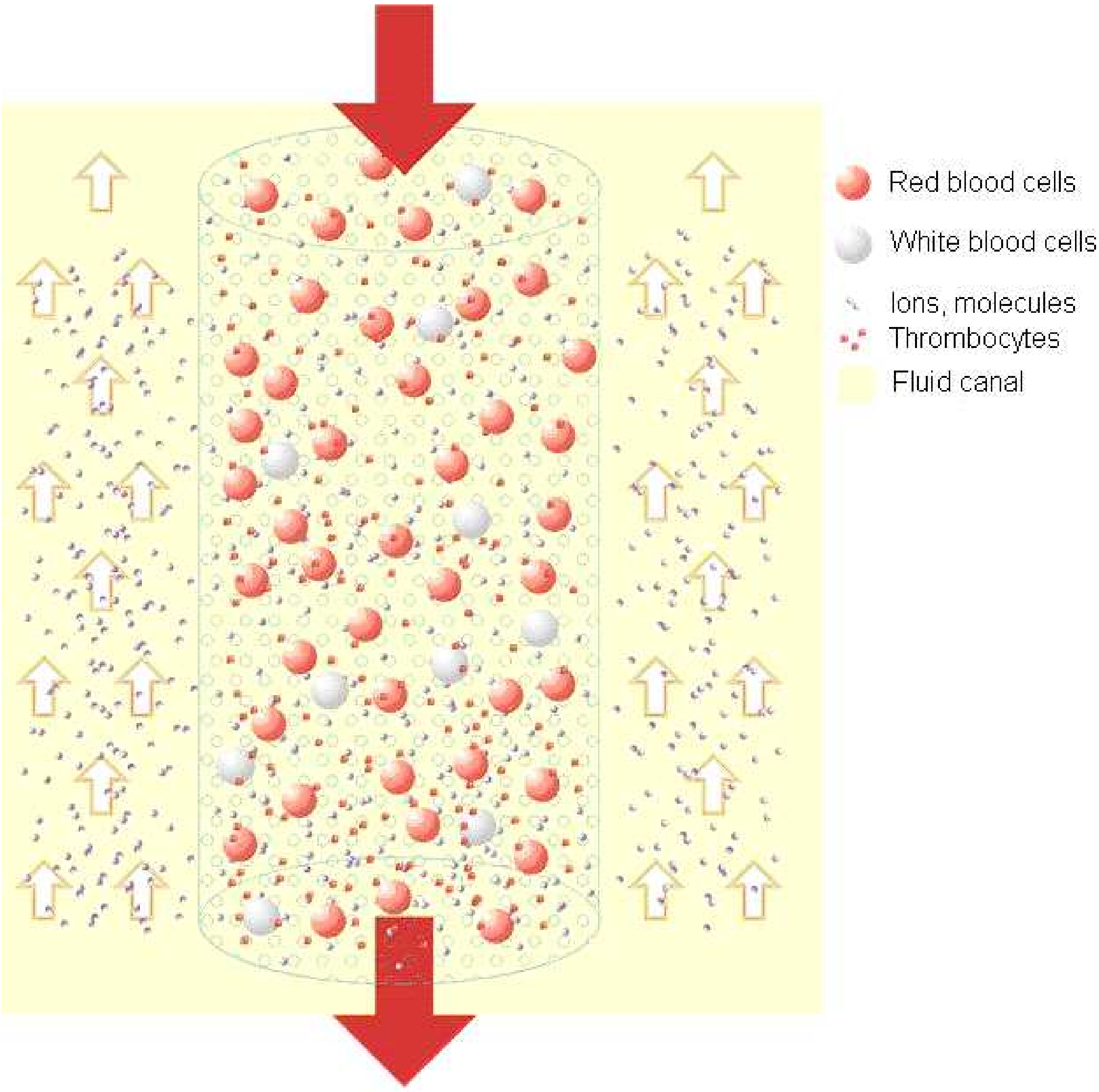

Fig. 1. *Model of blood flow in the dialyzer capillary.*

Materials and Methods

We have created the concept model of plasma dialysis, involving separation blood cells from the plasma before the dialyzer, allowing only for the passage of plasma through the dialyzer canal. After the filtration step, plasma is returned to be combined with previously separated blood cells before its re-infusion to the patient body (Fig. 2). For the dialyses and hemodialyses the fresenius 4008 S device was used.

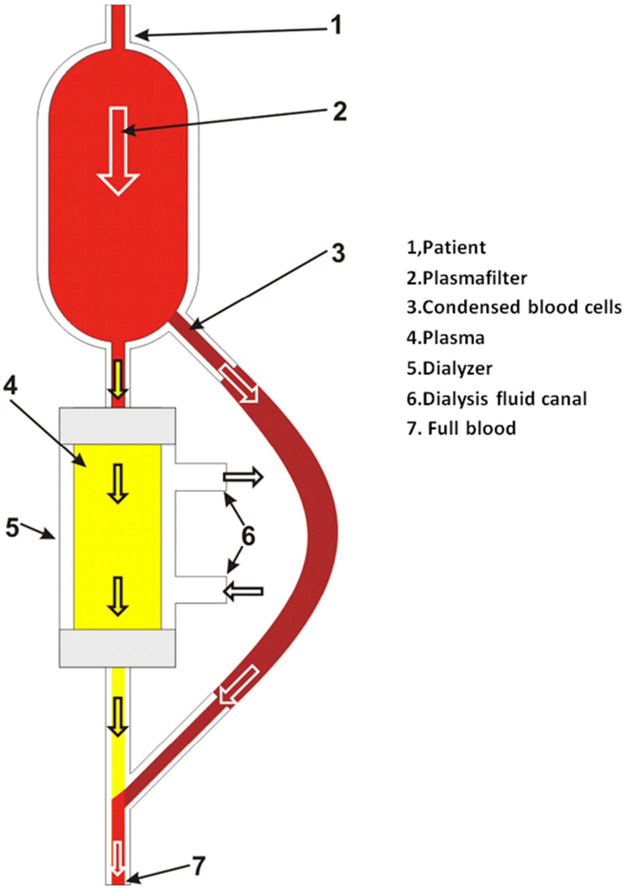

Fig. 2. *Schematic presentation of the presented plasma dialysis.*

Firstly, based on these assumptions, comparison of images of internal capillary walls obtain using an electron microscope after typical hemodialysis were performed. This stage of the study included images of the dialyzer capillary after passage of the peritoneal cavity trans due from of female patient with uncontrolled liver cirrhosis who participates in a program of repeated hemodialysis. All images were obtained under the same flow conditions and using the capillary and hemodialyzer model. Obtained images are presented on figures 3-6, demonstrating internal lumens of dialyzing capillaries under various magnifications, following a conventional hemodialysis.

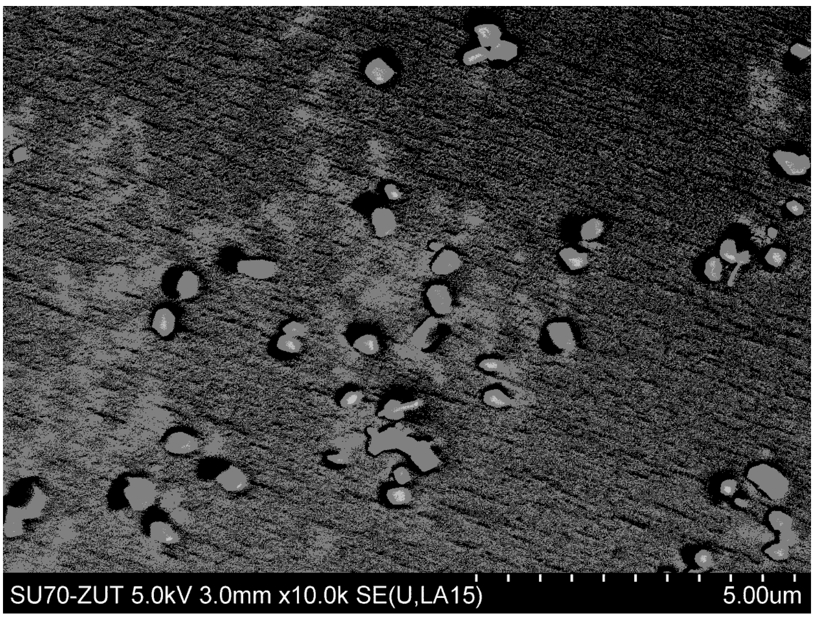

Fig. 3. *Light capillary dialyzer after hemodialysis (electron microscope 5 000).*

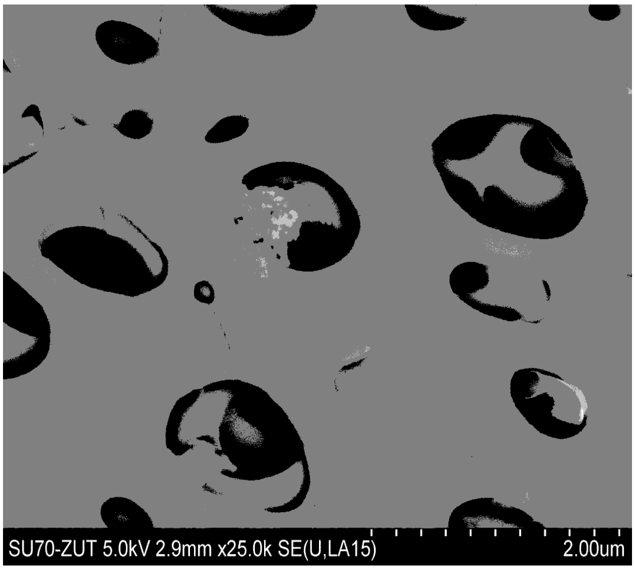

Fig. 4. *Light capillary dialyzer after hemodialysis (electron microscope 50 000x).*

Secondly, imaging of the capillary lumens following an investigation plasmadialysis, were performed. For this purpose standard imaging procedure with the scanning electron microscope Zeiss LEO was used. Comparison of capillary lumens from an electron microscope (magnification 50 000x) after a typical hemodialysis and after a plasmadialysis procedure is also presented and indicates decrease in the number of attached blood cells.

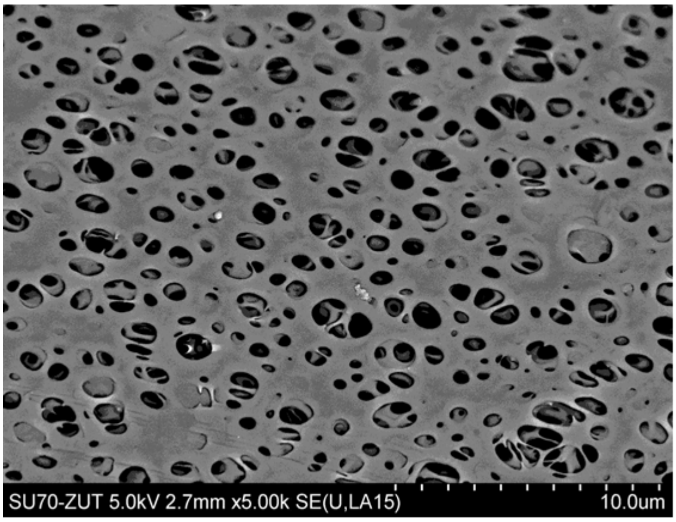

Fig. 5. *Light capilary dialyzer after plasma dialysis (electron microscope 20000x).*

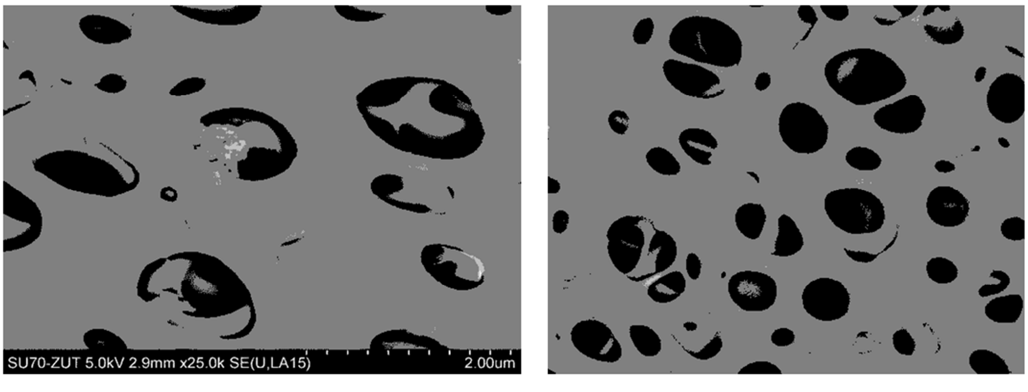

Fig. 6. *Light capillary dialyzer after hemodialysis (electron microscope 50 000x) and light capillary dialyzer after plasma dialysis (electron microscope 30 000x).*

Results

Subsequently a full blood clearance index was calculated, basing on the percent reduction of creatinine level before and after the dialysis both for the typical hemodialysis and an investigation plasmadialysis (Fig. 7-8).

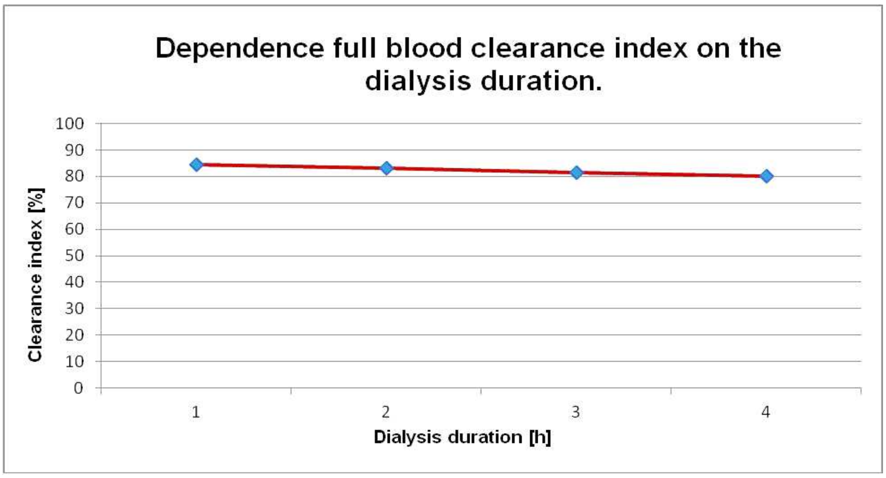

Fig. 7. Association between creatinine clearance index and time hemodialysis.

This index ranged 79-86% for the full blood and decreased over time during procedure, while was higher for plasmadialysis and ranged from 94-95%; furthermore no trend towards its reduction during the procedure was found.

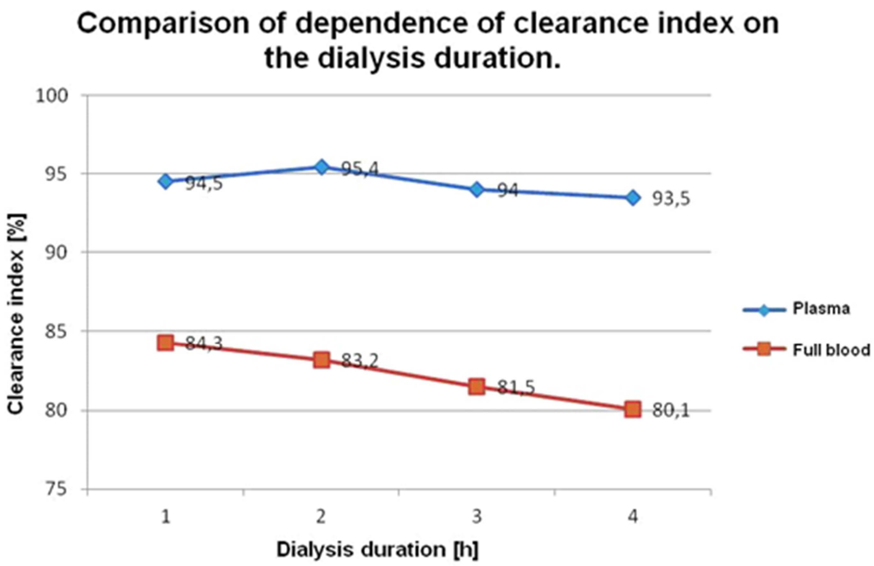

Fig. 8. Comparison of clearance index efficacy over time for hemodialysis and plasma dialysis.

Discussion

Based on these observations we may predict that suggested method of blood clearance may be more effective if compared to the conventional hemodialysis. In theory, one could perform the above mentioned plasma dialysis procedure using a parallel connection of a typical plasma filter and a dialyzer. However, such system would require withdrawal of a large amount of blood from the patients circulation (which may not always prove beneficial), while commercially available plasma filters provide relatively small amounts of separated plasma (up to approximately 50 ml/min), which would be insufficient [13-21].

Taking into consideration these practical aspects, we wish to suggest the concept for construction of a new dialyzer type. This dialyzer would simultaneously perform a process of separation of plasma and blood cells and perform the dialysis. Here we present two variants of such solution: rotary dialyzer (Fig. 9) and dialyzer with double capillary walls (Fig. 10).

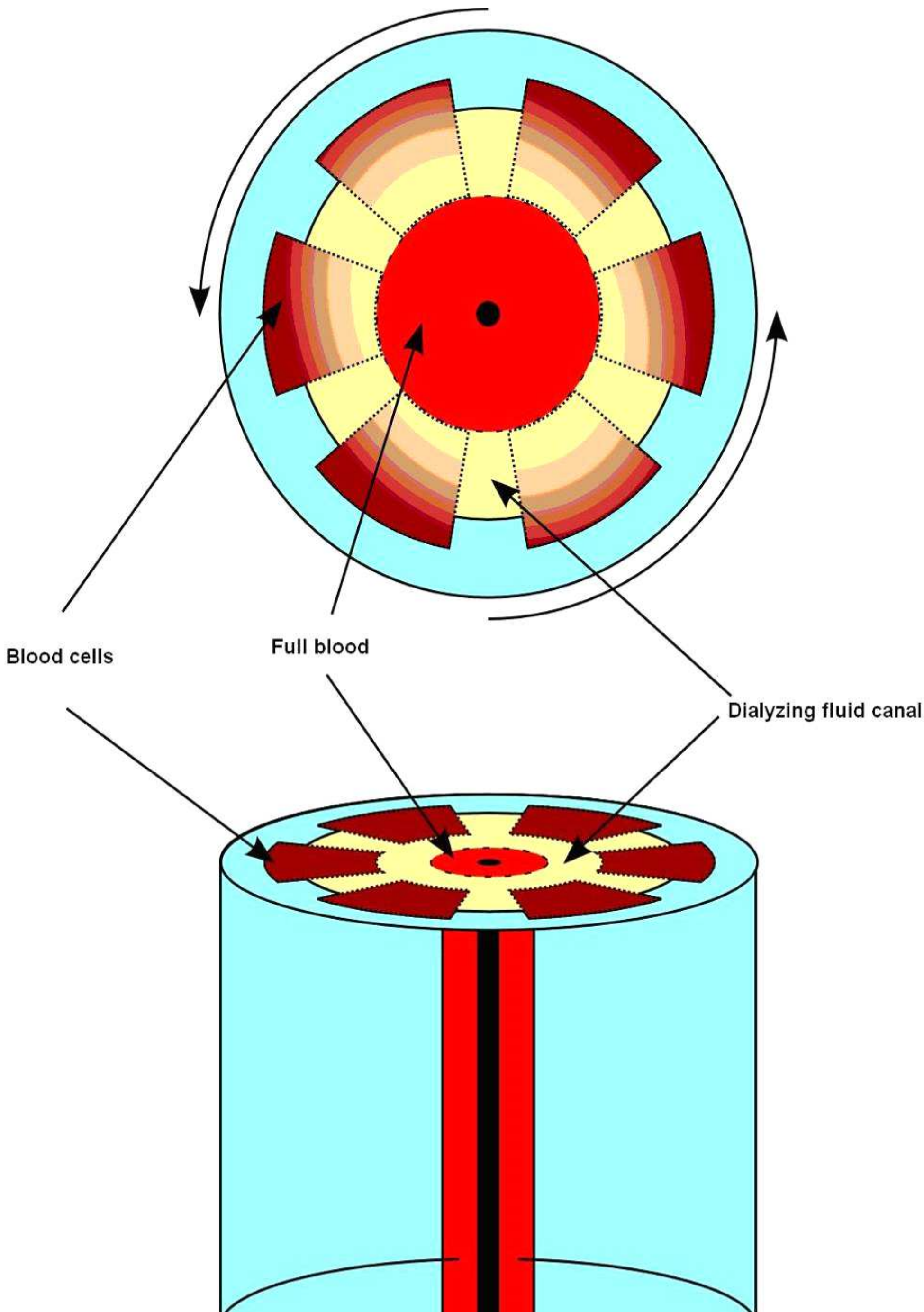

Fig. 9. *Rotary dialyzer.*

Such dialyzer would rotate during the procedure, resulting in accumulation of blood cells on its walls, while the plasma would remain in the central part and would be cleared through contact with flowing dialyzing fluid. Possible problems with manufacturing of such dialyzer include constructional problems and need to maintain leak-proof system both in the blood canal and fluid canal.

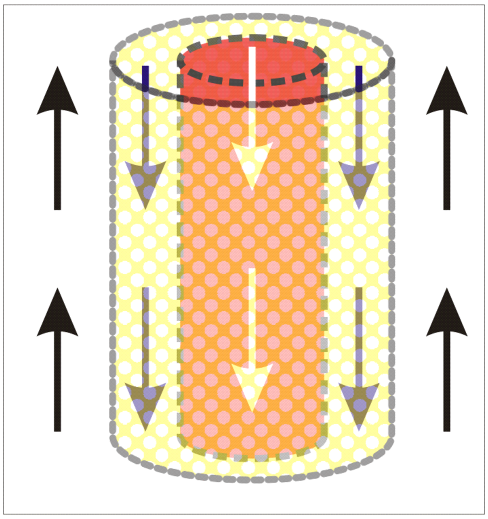

Fig. 10. *Dialyzer with double capillary walls.*

With this approach, full blood would flow though an inner capillary. Its walls would posses pores (approximately 3000 000 kDa in diameter) allowing the fluid part of the blood, plasma, to be evacuated outside this component. Plasma flowing through this space would contact a dialyzing fluid through typical dialyzing membrane (pores approximately 15 000 D in diameter) and would be cleared conventionally. We believe that such construction of a plasma dialyzer could be optimal.

This study presents a concept model for the plasma dialysis with the separation of the cellular blood components prior to the entry into the dialysis capillary. Benefits of these systems include stable efficacy and stability in time. The system was indicated to allow for the stable creatinine clearance. Construction of such devices may result in the progress of the dialysis methods and improvement of patient care. Following the construction of such plasma dialyzers and required clinical trials these devices may contribute to the following:

Improved plasma clearance if compared to the full blood, with estimated 20% higher efficacy compared to the hemodialysis based systems, efficient dialysis of patients even with relatively low blood flow (for example 100-150 ml/min) and low blood pressure, the duration and frequency of dialysis procedures could be notably reduced in selected patients. In the available literature we did not find the proposed similar solutions in terms of improving the efficiency of hemodialysis, which may indicate that it is our individual project [5, 7, 12]. Undoubtedly, this concept requires further study, debate and attempts to design a new prototype capillary dialyzer. Initial assumptions of our project were presented at the "Forum Nefrol." in 2013 [22].

Conclusions: Presented dialysis methodology is a concept for the improvement of dialysis. Its key features include better plasma clearance and higher efficacy compared to hemodialysis as well as possibility to use in the setting of the decreased blood flow and pressure. ■

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US Professor Dr. med. Krzysztof Dziewanowski was born 1946 in Cracow, Poland. He completed the medical studies in the Pomeranian Medical University in Szczecin (Poland) in 1970. He is a specialist in internal medicine, nephrology and clinical transplantation. He has been the head of the Centre for Neurological Transplantation Regional Hospital in Szczecin and researcher at the University of Szczecin for a long time. He had about 100 publications and several patents and inventions.
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References

[1] Davenport A. Early start renal replacement therapy for acute kidney injury-universal panacea or another case of over medicalization? *Hemodial Int*. 2015; 19: 12351.

[2] Shah SV, Shukla AM, Bose C, Basnakian AG, Rajapurkar M. Recent advances in understanding the pathogenesis of atherosclerosis in ckd patients. *J Ren Nutr*. 2015; 25: 205-208.

[3] Schneider AG, Bagshaw SM. Effects of renal replacement therapy on renal recovery after acute kidney injury. *Nephron Clin Pract*. 2014; 127: 35-41.

[4] Jablonski KL, Chonchol M. Recent advances in the management of hemodialysis patients: A focus on cardiovascular disease. *F1000Prime Rep*. 1000; 6: 6-72.

[5] Roy-Chaudhury P, Kruska L. Future directions for vascular access for hemodialysis. *Semin Dial*. 2015; 28: 107-113.

[6] Fissell R, Hakim RM. Improving outcomes by changing hemodialysis practice patterns. *Curr Opin Nephrol Hypertens*. 2013; 22: 675-680.

[7] Jacobson H, Klahr S, Striker G. Principles and practice of nephrology. *Mosby-Year Book (January 1995)*. 1995: 713-721.

[8] Kale-Pradhan PB, Woo MH. A review of the effects of plasmapheresis on drug clearance. *Pharmacotherapy*. 1997; 17: 684-695.

[9] Nenov D, Metodiev K. Combined treatment of immune nephropathies with plasmapheresis and immunosuppressants. *Biomater Artif Cells Artif Organs*. 1988; 16: 991-997.

[10] Weinstein R. Is there a scientific rationale for therapeutic plasma exchange or intravenous immune globulin in the treatment of acute guillain-barré syndrome? *J Clin Apher*. 1995; 10: 150-157.

[11] Weinstein R. Prevention of citrate reactions during therapeutic plasma exchange by constant infusion of calcium gluconate with the return fluid. *J Clin Apher*. 1996; 11: 204-210.

[12] Carter CE, Benador NM. Therapeutic plasma exchange for the treatment of pediatric renal diseases in 2013. *Pediatr Nephrol*. 2014; 29: 35-50.

[13] Kaplan AA. Plasma exchange in renal disease. *Seminars in Dialysis*. 1996; 9: 61-70.

[14] Madore F. Plasmapheresis. Technical aspects and indications. *Crit Care Clin*. 2002; 18: 375-392.

[15] Orlandini GC, Margaria R. Evaluation of the efficiency of a new hollow fiber plasmapheresis filter. *Int J Artif Organs*. 1983; 6 Suppl 1: 103-106.

[16] Kaplan AA. General principles of therapeutic plasma exchange. *Seminars in Dialysis*. 1995; 8: 294-298.

[17] Kaplan AA. Plasma exchange for non-renal indications. *Seminars in Dialysis*. 1996; 9: 265-275.

[18] Tan HK, Hart G. Plasma filtration. *Ann Acad Med Singapore*. 2005; 34: 615-624.

[19] Madore F, Lazarus JM, Brady HR. Therapeutic plasma exchange in renal diseases. *J Am Soc Nephrol*. 1996; 7: 367-386.

[20] Mokrzycki MH, Kaplan AA. Therapeutic plasma exchange: Complications and management. *Am J Kidney Dis*. 1994; 23: 817-827.

[21] Hajime N, Michiko A, Atsunori K, et al. A case report of efficiency of double filtration plasmapheresis in treatment of goodpasture's syndrome. *Ther Apher Dial*. 2009; 13: 373-377.

[22] Dziewanowski K, Drozd R. Plasmadialysis as alternative method to improve degree of the dialysis in patients with chronic renal failure (in polish). *Forum Nefrol*. 2013; 6: 150-154.