Blood Elements Activation in Hemodialysis – Animal Model Studies
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Abstract—Haemodialysis (HD) is a procedure saving patient lives around the world, unfortunately it brings numerous complications. Oxidative stress is one of the major factors which lead to erythrocytes destruction during extracorporeal circulation. Repeated HD procedures destroy blood elements and the organism is not able to keep up with their production. 30 HD procedures on healthy sheep were performed to evaluate effects of such treatment. Oxidative stress study was performed together with an analysis of basic blood parameters and empirical assessment of dialyzer condition after the procedure. A reversible decline in absolute leukocyte count, during first 30 min of HD, was observed. Blood clots were formed in the area of the blood inlet and outlet of the dialyzer. Our results are consistent with outcomes presented throughout the literature specifically with respect to the effects observed in humans and will provide a basis to evaluate methods for blood protection during haemodialysis.

Keywords—Animal model, blood components, haemodialysis, leukocytes, oxidative stress, sheep.

I. INTRODUCTION

HAEMODIALYSIS (HD) is a procedure that uses the extracorporeal circulation to remove waste products from blood, especially small and medium-sized molecules. This technique involves the use of semi-permeable membranes through which takes place the exchange of substances between blood and a specially prepared dialysis fluid. The treatment is performed periodically until the restoration of kidney function, until the kidney transplantation or even up to the end of patient's life. Treatments involving devices that have direct contact with the organism often associate different types of complications. This is a major problem in procedures using artificial organs [1], [2].

Blood of a haemodialysis patient is in constant contact with the material, which causes the activation of plates, leukocytes, mainly neutrophils, which release reactive oxygen species (ROS) leading to the destruction of the cellular components of blood [3], [4]. Oxidative stress is a major factor in red cell damage during extracorporeal circulation. A short interval between treatments causes inability of the body to regenerate and lagging production of new cells [5], [6].

Currently, there are many studies aimed at protecting the blood during such procedures. There are created new, more biocompatible materials, new assisting drugs. Surgical techniques with the use of artificial organs are still being developed and improved and therefore there is a need to search for new solutions that are tested in animal models. In this type of research it is very important to choose the appropriate test conditions in order to meet the expectations of modeling necessary organism functions.

In this work we have tested a suitable animal model and investigated the influence of extracorporeal circulation on the blood. We have modeled haemodialysis and studied a healthy animal response to irritants which are disposable parts of the artificial kidney in contact with the patient's blood, especially the effect of haemodialysis on blood cell counts in sheep model and compared it with literature reports regarding humans.

II. PROCEDURE - MATERIALS AND METHODS

A. Animals

Experiments were conducted on three adult, clinically healthy, male Merino sheep weighing 54-62 kg. A total of 10 HD treatments were performed on each animal. Permanent vascular access was obtained by percutaneous placement of a 14.5 French 28cm long dual-lumen haemodialysis catheter into the right jugular vein (vena jugularis) (Fig. 1). Sheep were premedicated (Xylazine 0.2mg/kg body weight iv) and with local infiltration anesthesia (2% lidocaine).

Fig. 1 Permanent vascular access

B. Haemodialysis Procedure

Experiments were performed using a Fresenius 4008B haemodialysis device on sheep standing in boxes without pharmacological sedation (Fig. 2). Four hour HD sessions
were performed three times a week with the use of polysulphone dialyzer Fresenius F4HPS and standard blood line (AV-Set, Fresenius MC, USA). Before the procedure, 5000 IU of sodium heparin (WZF Polfa SA, Poland) dissolved in 500mL Ringer's solution (B. Braun Melsungen AG, Germany) was administered as intravenous infusion. During the experiment heparin was introduced into the blood line at a constant rate determined in preliminary studies. 36L of blood was processed within 4 hours of HD (blood pump speed: 150mL/min), total ultrafiltration was set at 200mL. Dialysate flow rate (composition: Na\(^{+}\) 142.0, K\(^{+}\) 3.0, Ca\(^{2+}\) 1.5, Mg\(^{2+}\) 0.5, Cl\(^{-}\) 110.0, HCO\(_3\)\(^{-}\) 32.0mmol/L, glucose 1.0g/L) was 500 mL/min.

In the first 15 minutes of HD the total number of leukocytes decreases (average 20%), and after 30 minutes, begins to return to normal level. After 4 hours, of the procedure an increase in the number of leukocytes is observed. In samples performed three times a week with the use of polysulphone dialyzer Fresenius F4HPS and standard blood line (AV-Set, Fresenius MC, USA). Before the procedure, 5000 IU of sodium heparin (WZF Polfa SA, Poland) dissolved in 500mL Ringer's solution (B. Braun Melsungen AG, Germany) was administered as intravenous infusion. During the experiment heparin was introduced into the blood line at a constant rate determined in preliminary studies. 36L of blood was processed within 4 hours of HD (blood pump speed: 150mL/min), total ultrafiltration was set at 200mL. Dialysate flow rate (composition: Na\(^{+}\) 142.0, K\(^{+}\) 3.0, Ca\(^{2+}\) 1.5, Mg\(^{2+}\) 0.5, Cl\(^{-}\) 110.0, HCO\(_3\)\(^{-}\) 32.0mmol/L, glucose 1.0g/L) was 500 mL/min.

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taken on input and output of the dialyzer after dialysis no significant changes were noticed (Fig. 3)

Additional studies were carried out to exactly determine at what time does the effect, seen clearly in the 15th minute, start and how long does it last. The results are shown in the graph (Fig. 4). It was observed that the decrease in the number of leukocytes starts after five minutes and lasts for 15 minutes, then begins to occur increase of WBC count and stabilization on the initial level in the 30 minute.

Differential WBC counts also changed during HD. In the first 15 minutes of the extracorporeal circulation statistically significant (p≤0.05) decrease in the total number of neutrophils was observed in all animals. After 30 minutes neutrophil count returned to the level from the beginning of the extracorporeal circulation. Four hours of HD resulted in a significant increase in neutrophil count (p≤0.05). There were no significant differences in the neutrophil count between venous and arterial lines at the beginning and after 4 hours of HD (Fig. 5).

Lymphocyte count did not change significantly during the first 30 minutes of HD. Significant increase in lymphocyte count was observed after 4 hours of HD (Fig. 6). There were no significant changes in eosinophil and monocyte counts during the experiments.

Haemodialysis caused the production of TBARs. The highest level of TBARs was observed in venous line after 5 minutes of HD (Fig. 7). Oxidative stress measured after 4 hours of HD in the arterial and venous lines shows no statistically significant changes (Fig. 8). The effects of haemodialysis in arterial line on the amount of substances reacting with thiobarbituric acid are presented in Fig. 9.
IV. CONCLUSIONS

In 5th minute of HD we observed an increase in TBARs production as an indicator of oxidative stress caused by blood passage through the dialyzer. This influences the, TBARs production dependent, decrease in WBC count lasting up to 15th minute of HD that was not permanent. Then we observed a gradual increase in leukocyte number until 30th minute of HD. After that WBC count stabilizes around the number from the HD beginning. Until the end of HD there are no more signs of changes in TBARs production and WBC count. Blood clot formation was observed on the surface of a dialysis membrane, both the input and the output of the dialyzer. This effect may be associated with the deposition of activated leukocytes, neutrophils and platelets on the surface of the dialyzer membrane [8]. Significant increase in the level of lipid peroxidation in peripheral blood, at the HD beginning, indicates severe oxidative stress and may indicate a weakening of the body's antioxidant defense mechanisms. A similar effect was observed in patients treated with dialysis.

Transient leukopenia during HD is a well-known phenomenon that has been observed during HD with cellulose membranes [9]. It results from complement activation due to the contact of blood with bioincompatibile material. This causes activation of neutrophils, transmigration between endothelial cells into the surrounding tissues and the pulmonary sequestration [10]. The development of more biocompatible materials for dialyzer membrane production allows limiting the process, although it is not completely eliminated. We have shown that the contact of healthy sheep blood with the polysulphone membrane results in a temporary decrease in the total leukocyte count, which is caused by a decline in neutrophil count. Number of cells in the remaining populations of WBC did not change at the start of HD. Transient neutropenia well correlated with an increase in oxidative stress level. This suggests that oxidative stress occurring in the course of HD is largely related to the oxidative burst of phagocytes after non-specific activation by a dialyzer membrane.

Patients with chronic kidney disease (CKD) exhibit elevated levels of oxidative stress. On one hand, it may be one of the factors responsible for triggering of and progression CDK. On the other hand, it may be the result of the disease and the one of the complications related to the treatment with HD [11], [12]. It is also postulated that oxidative stress plays a role in the development of cardiovascular disease in the course of CKD [13]. This is the reason for searching for methods to reduce the oxidative stress in CKD patients. Our preliminary experiments on healthy sheep showed that HD procedure itself even when dialyzers made of modern materials are used causes the activation of leukocytes and increases the level of oxidative stress. They also provide a part of preliminary study on the methods of protection of blood components during the extracorporeal circulation.
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