PHYSICO-CHEMICAL INVESTIGATIONS IN REGENERATION OF THE DIALYSING FLUID

I. Medical Department, University Hospital, Homburg/Saar, Germany

The regeneration of the dialysing fluid is the precondition for a dialysis system with a small recirculating volume of fluid. Such a dialysis system would allow us to perform chronic dialysis more easily, especially at home. Also a compact blood dialyser like Bluemle’s concept of a portable dialyser (Bluemle, Ushakoff and Murphy, 1965) requires the volume of dialysing fluid to be reduced without sacrificing dialytic capacity.

Dr. Twiss has just reported on his dialysis system incorporating the use of activated charcoal (Twiss and Paulsen, 1966). The adsorption of nitrogenous metabolites on activated charcoal was also investigated by Sparks, Blaney and Lindan (1965; 1966) and by Kolobow and Dedrick (1966). The problems in regenerating the dialysing fluid do not consist only in eliminating the waste products. It is also necessary to correct changes of electrolyte concentrations in the dialysing fluid. If these two connotations could be accomplished, the system nevertheless would be incomplete. By the elimination of urea etc. the dialysing fluid becomes hypotonic to the body fluids and the resulting osmotic transfer of water would overhydrate the patient. The third problem is therefore to increase the osmolarity of the dialysing fluid and to extract water in certain quantities. To solve these three main problems we developed the following concepts:

1. Elimination of waste products by adsorption, using activated charcoal. It is the same concept used by Twiss (1965; 1966) Kolobow et al. (1966) and Sparks et al. (1965; 1966), stimulated by the paper of Yatzidis (1964).

2. Correction of electrolyte concentrations applying ion exchange resins.

3. Increasing the osmolarity of the dialysing fluid and guiding the water extraction by a simple, non-mechanical system, delivering glucose and taking up water.

Since December 1964, we have investigated these possibilities in vitro.

Our experiments demonstrate:

1. For the adsorption we used ‘Activated charcoal for gas chromatography, Merck’.

Figure 1 shows the adsorption isotherms for urea, glucose and creatinine. The concentrations in the test fluid are plotted against the quantities adsorbed by 100 g of charcoal in equilibrium. The curves demonstrate the corresponding total capacity of adsorption for each concentration of the fluid. These total capacities would also be reached in perfusion of charcoal columns. The urea adsorption is the smallest. Glucose is adsorbed a little better, an effect not wanted but to be regarded. The adsorption of creatinine is reduced to 1/10. We also tested phenol. It is adsorbed in much greater quantities than creatinine. The slope of the isotherm therefore would be much higher. Our results are as follows:

A column of 100 g activated charcoal is sufficient to adsorb the daily quantity of creatinine and phenol. On the contrary 10-20 kg of charcoal would be necessary to adsorb the daily supply of urea. In regenerating the dialysing fluid the tested charcoal is therefore not com-
pletely sufficient for the elimination of urea. For this purpose more suitable adsorbing media shall be tested in further investigations.

2. For the correction of electrolyte concentrations we applied ion exchange resins.

Each exchange of ions between a resin and an electrolyte solution tends to reach an equilibrium. It is determined by the mixing proportion of the ions on the resin dependent on the different affinity of ions and the mixing proportion in the fluid. We prepared the resins by loading with exchangeable ions in certain proportions. By using this preloading we can guide

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*Fig. 1.* Adsorption isotherms for creatinine, glucose and urea by 37°C.

*Fig. 2.* The sodium, potassium, and calcium concentrations of different test fluids after perfusion of a preloaded 100 g resin column.
the ion exchange in such a manner that the concentrations of the different ions in the fluid perfusing a column of resin are automatically normalized, independent of the initial concentrations.

We used DOWEX 50W × 8 as cation exchange resin and DOWEX 2 × 4 as anion exchanger and performed the preloading by the technique of Kissack, Giedman, Biala, Lerner and Karlson (1963) or by perfusion with fluids of normal electrolyte composition. Figure 2 shows for instance the sodium, potassium and calcium concentrations of testfluids perfused through a column with 100 g of resin. The potassium concentration is normalized, whether the initial concentration is 10.5 or 2 mEq/L. The concentration of calcium is corrected too. For anions also there exists such automatic regulation for the electrolyte concentrations. But all these effects are limited to a certain volume of perfusing fluid.

3. The system for the regeneration of the osmolarity and for the water extraction consists simply of VISKING tubes. Each tube contains 23.5 g of glucose, a quantity which induces an uptake of 100 ml of water. About 90% of the glucose diffuse into the dialysing fluid, raising its osmolarity.

For testing the efficiency of all three regeneration units inserted in the recirculating dialysing fluid, we have simulated a clinical dialysis. One typical result of these experiments is shown in Fig. 3.

![Figure 3](image)

**Fig. 3.** The urea, creatinine, and phenol concentrations in the 'blood' and the dialysing fluid in an experiment simulating a clinical dialysis. (Volume of the 'patients blood' 30 l, volume of the dialysing fluid 10 litres.)

All results of the experiments demonstrate that a dialysis system with recirculation and regeneration of a small volume of dialysing fluid is practicable in principle. Before it can be used for patients several problems have still to be solved. In particular the specific capacity of the regeneration units should be higher.
REFERENCES


DISCUSSION

The Chairman: Il est certain que toutes ces méthodes qui tendent à permettre une réduction du volume du bain de dialyse ont actuellement un intérêt tout particulier.

Est-ce que quelqu'un a des commentaires à faire sur ces deux communications?

Versaci (USA): As points of reference, I shall mention the work of Arwin Weinstein (Trans. Amer. Soc. Artif. Intern. Organs, 10, 268 (1964) (from Wisconsin, with reference to drugs, and studies done by Dunea and Kolff, (Trans. Amer. Soc. Artif. Intern. Organs, 11, 178 (1965)), of a small group of patients using charcoal and also the fact that the small unit was described by Sparks initially in 1964.

Further, I would like to ask a couple of questions as to the specific charcoals that are being used because there is such a variety in the method of preparation: they do have a change in the structure of the charcoal by the method of steam preparation, time-duration and temperature.

I must compliment both groups on their very fine work.

Jutzler (Homburg/Saar): We used activated charcoal from Merck in Germany. But I cannot answer about the preparations.

Twiss (Rotterdam): We used two different kinds of charcoal, one American brand and one Dutch brand. We did some absorption experiments on both brands and they had not much difference in absorption capacity.

The Dutch brand contains some sulphate ions but the dialysate-charcoal mixture has only a concentration of about one-half mEq/litre.

The Chairman: Any other question?

Kolobow (Bethesda): In connection with the two previous papers, there was reference to a re-circulating system. I think they are limited by one fact, namely that the activated charcoal is reasonably large in size and does not permit to pass directly through the units, I am sure.

We have been concerned with the same problem. We have, however, used extremely fine activated charcoal powder, the particle sizes of which range from about 4 to 5 microns in diameter.

The advantage of this material is that the total equilibrium can be achieved with the surrounding media within a few seconds instead of half an hour or twenty minutes as reported earlier. (See Demonstration in these Proceedings. Ed.).