DIALYSATE CAPACITY AUGMENTATION WITH ACTIVATED CARBON SLURRY

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We have been impressed with the size limitations imposed upon current haemodialysers by the need for large quantities of dialysis fluid. One can readily foretell improvements in designing a more compact haemodialysis system; it would seem to be impossible on theoretical grounds to 'compress' the huge dialysate quantities to a volume that could be truly called 'portable', let alone wearable.

Yatzidis (1964) recently showed that haemoperfusion through an activated carbon cartridge removed certain metabolites such as creatinine, uric acid, indican, phenolic compounds, and organic acids. Unfortunately, this approach does not permit electrolyte adjustment or water removal; removal of urea was also insignificant.

A new haemodialysers was reported by one of us in 1964 (Kolobow et al., 1964). Further improvements led to a system that permitted high dialysance at dialysate flows down to a few ml/min. There appeared the possibility of achieving efficient haemodialysis at extremely low dialysate flow rates provided the dialysate capacity could be increased to equal that of conventional high-flow dialysate (300 ml/min is in this context considered to be high-flow). If proven feasible, total dialysate required per treatment could be reduced to possibly a few litres or less. We chose to add ultrafine activated carbon to the dialysate and to study its effect in clearing adsorbable metabolites (Kolobow and Dedrick, 1966).

Dialysance studies were conducted with a short segment of 0.9 mil thick cellophane tubing* supported from within by a 14 \times 14 mesh polyethylene screen. In these studies, the dialysate was distilled water. High dialysance is obtained at dialysate flows down to 4 ml/min (Fig. 1). The term dialysance used here is a true overall mass-transfer coefficient obtained by dividing the rate of mass transfer per unit area by the mean concentration difference between

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the dialysate and the ‘blood’ phase. This is consistent with our previous usage of the term but differs from the more conventional one (Wolf et al., 1951). Sodium chloride dialysance at dialysate flows of 150 ml/min is 280 ml/(min)(m²). At flows of 10 ml/min it falls off to 150 ml/(min)(m²) and reaches 100 ml/(min)(m²) at flows of 4 ml/min.

To study the effect of dialysate capacity augmentation, we placed a longer strip of our cellophane tubing, supported from within by a polyethylene screen, in a 4-5 litre synthetic ‘blood’ bath containing either hippuric acid or creatinine; sodium chloride was added in a number of runs (dialysate in our system is always sucked through the lumen of the tubular membrane, the presence of the polyethylene screen preventing total collapse of the tube). ‘Blood’ phase agitation was accomplished with an air bubbler. The dialysate consisted of a suspension of very fine activated carbon powder. We chose activated carbon* with a mean particle size of 4-5 microns to prevent plugging the dialysate compartment and to permit achieving near total equilibrium between the diffused metabolites and the carbon in the time required for the carbon to traverse the strip. This was considered most important as use of a single pass dialysis system was anticipated.

Figure 2 shows dialysance data from the above experiment. As the effect of ultrafiltration has been properly accounted for (Kolobov and Dedrick, 1966), the data indicate true dialysance. The black points denote dialysance as obtained with activated carbon in the dialysate; open points denote dialysance obtained with distilled water. For hippuric acid, little effect of carbon is seen on dialysance; a slight drop appears for creatinine, and a more significant one for NaCl (the latter being non-adsorbable) in the presence of carbon slurry.

Figure 3 shows clearance vs. dialysate flow. The straight line indicates clearance limited by dialysate flow. At all flows studied, activated carbon overcame the limitation imposed by dialysate flow and exceeded it by a considerable margin. Our greatest interest centers on extremely low dialysate flow rates; at flows as low as 3 ml/min, a hippuric acid clearance of 42 ml/min can be attained, or one half the maximum clearance for the strip employed, based on a 1 m² surface area. We have not made adjustments in net dialysate flow due to ultrafiltration which was determined separately and found to be about 600 ml/(hr)(m²), or about 10 ml/(min)(m²). Provided one is referring to a 1 m² surface area, an input of 3 ml of carbon


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slurry would result in a final exit flow of 3 ml plus 10 ml, or 13 ml/min. The net result is a dilution of the slurry, but at the same time a higher efficiency due to greater dialysate flow.

Our efforts have been confined to using activated carbon as a 'sink' for metabolites. It is apparent, however, that other materials as well could be found useful and should be considered.

Our work suggests that home dialysis for readily adsorbable metabolites utilizing only 1-2 litres of activated carbon slurry in a single pass system may be feasible provided the artificial kidney used shows great efficiency at sufficiently low dialysate flow rates. Presently commercially available designs are not suitable; however, this concept is adaptable to the improved version of our artificial kidney, and it should be possible to obtain over 90% clearance for adsorbable materials in a single pass depending on blood flow rates used (Kolobow et al., unpublished data).

REFERENCES