Three-hour Maintenance Dialysis Combining Direct Haemoperfusion and Haemodialysis

M ODARA, Y TABATA, H KOBAYASHI, Y NOMURA, M SOMA, H HIRASAWA, H SATO, E SUENAGA*, K NABETA*
Chiba University, School of Medicine, Chiba and *Bio-Medical Research Institute, Teijin Ltd, Tokyo, Japan

Introduction

Activated charcoal adsorbs creatinine, uric acid, middle molecular weight substances, etc., but not urea, electrolytes or water. Since the first clinical use of the artificial kidney by Kolff et al in 1944, the principle of haemodialysis has been the phenomenon of diffusion between blood and dialysate across a semipermeable membrane. Small molecular weight metabolites in the blood are easily removed by dialysis and ultrafiltration. However, middle molecular weight substances are only poorly removed during long term dialysis.

In 1970, Chang et al developed direct haemoperfusion using albumin-coated, activated coconut charcoal. They reported the results of two hours haemoperfusion instead of regular haemodialysis for maintenance haemodialysis patients. Coconut charcoal has an irregular shape with many sharp edges and is not very hard. Therefore it is difficult to encapsulate completely with a thin membrane. These factors lead to release of fine particles from the encapsulated charcoal into the blood.

METHODS AND MATERIALS

We used the new petroleum activated carbon treated with high temperature. This carbon has no volatile organic substances after this treatment, the ash is less than 0.03% by weight and includes traces of Co, Ni, Cr, Cu, Fe and Mg. The carbon particles are 0.6 mm in average diameter and have 1,000 M²/g of adsorption surface area (by BET method). Other characteristics are as follows: (1) spherical form, (2) considerable hardness, and (3) high adsorption capacity. Due to the
spherical form, it is easy to coat with a thin and homogeneous film. In this respect it is superior to coconut charcoal.

Figure 1 shows the surface of this carbon viewed with the scanning electron microscope.

The module is made by the following procedure: sieving (> 32 mesh), acid and alkaline treatment, washing and drying, microencapsulation with collodion (by Chang's method), drying, autoclaving and filling a column, under sterile conditions, with 130g of capsulated carbon.

Figure 2. Schema of our newly devised dialysis system combining direct haemoperfusion and haemodialysis
Figure 2 shows a new dialysis system comprising this column and a hollow fibre kidney in series. The hollow fibre kidney removes water and urea, adjusts electrolytes and acid-base balance. The composition of dialysate for this system is Na 130 mEq/l, K 0–3.5 mEq/l, Ca 3.5–4.5 mEq/l, Mg 1.5 mEq/l and bicarbonate 40 mEq/l. Flow of the dialysate is 500 ml/min by single pass and the negative pressure applied to the hollow fibre kidney is 400–500 mmHg. Duration of dialysis is only 3 hours.

This 3 hour maintenance dialysis has been applied to two patients. One is a 47-year old male, who has received 8 years of chronic dialysis three times a week. The other is a 27-year old male with a history of only 2.5 months chronic dialysis twice a week. Both patients started this system in August 1975.

RESULTS

Two hundred and fifty dialyses have been performed in the 10 months between last August and this May. These two patients have kept well with good blood chemical data. During 3 hours dialysis, an average of 2,043 ml of water was removed in each dialysis. The average blood flow was 202 ml/min.

![Graph showing changes in blood cells during 3 hours dialysis](image)

Figure 3. Changes of blood cells during 3 hours dialysis

Figure 3 shows the blood cell changes during 3 hours perfusion. RBC changes from $155 \times 10^4 \pm 35.7 \times 10^4$ to $164 \times 10^4 \pm 37.5 \times 10^4$, a 5.8% increase. WBC changes from $3,877 \pm 1,265$ to $4,203 \pm 1,361$, a 8.4% increase and the platelet count changes from $168,552 \pm 66,361$ to $182,257 \pm 77,000$, a 8.1% increase.

The reduction in urea, creatinine and uric acid are shown in Figure 4. BUN: $77.8 \pm 29.03$ to $43.7 \pm 25.55$ mg/dl or 43.8%; creatinine: $11.6 \pm 3.03$ mg/dl to $5.7 \pm 3.50$ mg/dl or 50.9%; uric acid: $9.3 \pm 1.47$ to $3.6 \pm 1.17$ mg/dl or 60.9%.

The change in total protein is from $7.2 \pm 0.65$ g/dl to $7.4 \pm 0.72$ g/dl or a 2.8% increase. The change in albumin is from $3.8 \pm 0.34$ g/dl to $4.0 \pm 0.42$ g/dl,
Figure 4. Reduction of BUN, creatinine and uric acid during 3 hours dialysis

a 5.3% increase. The effect on the blood electrolytes is as follows: Na 138.5 ± 2.56 to 138.8 ± 2.76 mEq/l; K 5.2 ± 1.48 to 3.6 ± 0.77 mEq/l; phosphate 4.8 ± 1.81 to 3.5 ± 1.31 mg/dl and Ca 7.9 ± 0.86 to 9.5 ± 1.32 mg/dl.

The change in SGOT from 22.7 ± 15.14 to 26.4 ± 14.3 mU/ml has no significance. pH and BE alter during the three hours. pH changes from 7.361 ± 0.035 to 7.463 ± 0.033 and BE to 2.1 ± 4.07 from −4.7 ± 3.91. There is no change of pO₂ from 90.4 ± 13.3 to 92.7 ± 11.0 mmHg.

During this 3 hours dialysis, 6,000 units of heparin were used in each dialysis for systemic heparinisation.

Figure 5 shows predialysis BUN, creatinine and uric acid levels for patient 1

Figure 5. BUN, creatinine and uric acid pre-dialysis levels in case 1, 47-year old male, with 3 times a week dialysis

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from May 1975 to May 1976. Before August 1975 he was treated with the Mera
cell kidney (surface area 1.0 m²) for 5 hours at a time. From the beginning of
August 1975 he was treated with this new system over 3 hours. At the beginning
of this study, 100 g of charcoal and the Asahi hollow fibre kidney (surface area
0.4 M²) were used. The level of BUN increased to 145–155 mg/dl. This suggested
that the capacity of this system was too small for him. Then we changed to 130 g
of charcoal and the 1.3 M² hollow fibre kidney. After this, his level of BUN,
creatinine and uric acid decreased significantly to the usual maintenance level.
During 250 dialyses in these two patients, there have been only three episodes
of disequilibrium symptoms, one of headache and two of chills and fever.

DISCUSSION

In maintenance dialysis, removal of water and adjustment of electrolytes and
acid-base balance are essential. For this reason, we applied both direct haemo-
perfusion and haemodialysis with the hollow fibre kidney to patients with chronic
renal failure. Although Chang et al (1970) were afraid of the reduction in plate-
lets during haemoperfusion, in our series there has not been platelet depletion
but platelet increase, suggesting that our charcoal is protected with a perfect
membrane which prevents platelet adhesion.

By using 130 g of charcoal and the 1.3 M² surface hollow fibre kidney in 3
hours perfusion, the removal capacity for urea, creatinine and uric acid rises to
1.5 to 2.5 times that in ordinary dialysis. Besides, middle molecular weight sub-
stances may be adsorbed by this charcoal. This characteristic allows us to cut
dialysis time to half. Three-hour maintenance dialysis helps patient rehabilita-
ion and will allow the use of one artificial kidney machine for 2 or 3 shifts in one day.

Our charcoal does not cause a fall in blood cells and coagulation factors, and
the newly devised dialysis system combining direct haemoperfusion and haemo-
dialysis is useful for the dialysis of all kinds of chronic renal failure patients, not
only for maintenance but also as an introduction. Of course, as an adsorption
type of artificial organ, it may be useful for hepatic coma.

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