Short Time Dialysis with 2 m² Hollow Fibre Kidney

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Introduction

The goal of long-term haemodialysis is to bring about complete rehabilitation in chronic renal failure patients. At present, nearly 600 haemodialysis patients are under our care, most of whom work daily. After work they attend hospitals for night dialysis. By shortening each dialysis to three hours, patients’ rehabilitation would be achieved more easily.

With the square-metre hour hypothesis (Babb et al, 1971) in mind, we have developed a two square metre (2m²) Hollow Fibre Kidney (HFK) and a recirculating dialysate supply system. Short-time dialysis in which patients experience no side effects is performed successfully with these developments without affecting dialysis efficiency.

MATERIALS AND METHODS

Our theoretical study of the relationship between dialysance and blood flow rate makes it clear that increased surface area as well as high dialysate and blood flows are required for the realization of short-time dialysis (Maeda et al, 1974). In the clinical study it is understood that in order to get results comparable to conventional dialysis, a blood flow rate of 300 ml/min is required for short-time dialysis (3 hours) by 2M² HFK (ASAHI Jumbo).

The ASAHI Jumbo

The ASAHI Jumbo is a U-shaped HFK as shown in Figure 1. In this dialyser, 8,000 hollow fibres of cuprammonium rayon of length 36 cm and inner diameter 260 μ are used. It has 2M² effective surface area with a priming volume of 180 ml. Ultrafiltration, unlike the conventional HFK, is produced by the pressure in the
blood compartments. Dialysances for urea, creatinine, uric acid, vitamin B\textsubscript{12} and Enramycin are given in Figure 2.

The Recirculating Dialysate Supply System

The dialysate supply system consists of two compartments as shown in Figure 1. One is a 10L canister for the coil and the other is a 30L batch-type tank. The 40L of dialysate is circulated through the canister and tank at a flow of 1 L/min.

![Diagram of Asahi Jumbo and recirculating system for short-time dialysis.](image)

A cylinder for adsorbents of 500 g activated charcoal and 200 g alumina is placed in the 30 L tank. The dialysate is recirculated through the tank being cleansed by the adsorbents. The dialysate is pumped upwards from the bottom centre of the U-shaped dialyser and passes through fibres at 8–16 L/min, making the most of dialyser efficiency.

The Artificial Glomerulus

The body fluids are easily controlled by the extracorporeal ultrafiltration method (ECUM) (Kobayashi et al, 1972). The theory of the method has been applied to a small HFK or the artificial glomerulus. The small HFK is of high permeability and can be placed at legs or arms (Figure 3). It incorporates 2,000 hollow fibres of effective length 250 µ, with a surface area of 0.157 m\textsuperscript{2}. It has an ultrafiltration rate of 0.8 ml/hr/mmHg.

Clinical Data I

A patient, after three years treatment by conventional dialysis, has been treated with 2M\textsuperscript{2} ASAHI Jumbo and a recirculating system with adsorbents for one year. Before starting short-time dialysis, he was completely rehabilitated on 6-hr dialysis three times a week. His creatinine clearance was 0 ml/min and his clinical data on 6-hr dialysis are shown in Table I.
He was transferred to 3-hr dialysis using the ASAHI Jumbo with a blood flow rate of 300 ml/min in September, 1973. As is clear from Table I, his pre- and post-dialysis blood concentrations of the various substances are almost the same as for 6-hour dialysis, whilst his weight has increased and his anaemia improved.

As shown in Figure 4, although BUN removal rate is inadequate, removal rates of creatinine, uric acid and potassium are almost the same and phosphate removal has increased. The increased rate of calcium is unsatisfactory, but its pre-dialysis blood level is higher than 6-hr dialysis (see Table I), which is possibly more advantageous in terms of homeostasis.

With respect to acid-base balance, on a 3-hr dialysis schedule, the pre-dialysis pH is 7.332, pCO₂, 35.5 mmHg and HCO₃, 18 mEq/l. Post-dialysis pH is 7.438, pCO₂, 30.7 mmHg and HCO₃, 21 mEq/l, illustrating correction of acidosis. The patient experiences no unpleasant feelings, maintains well-being and is fully rehabilitated.

Clinical Data II

The artificial glomerulus is placed on a lower limb and connected to the external shunt made near the kidney. The blood flows in the kidney as in a conventional dialyser and the dialysate outlet is closed and ultrafiltration is obtained from the inlet. For the heparinisation, 10,000 units heparin-Ca is given intramuscularly. The ultrafiltration rate is 200 ml/min, making 1,600 ml ultrafiltrate in eight hours. The apparatus is of small size and the patient is able to do light work while wearing it.

DISCUSSION

The development of a high-efficiency membrane with increased surface area as well as increased blood flow rate is required for short-time dialysis. Moreover, it
Figure 2. Dialysance of Asahi Jumbo.

Figure 3. Artificial glomerulus.

Figure 4. Removal rates of substances by 6-hr and 3-hr dialysis.
is important to achieve non-symptomatic dialysis. For the treatment of overhydration, ultrafiltration is performed using a conventional dialyser without dialysate. In this process, we could find no changes in blood osmotic pressure or unpleasant side effects, even with a high fluid removal rate (Kobayashi et al, 1972).

The recirculating system with adsorbents now in use for three years causes far fewer side effects than the single-pass system (Maeda et al, 1973). Possible reasons for this are (1) because of the constant dilution in the single-pass system, changes in the osmotic pressure of the dialysate occur easily and (2) urea removal is gradual. We accept a Na\(^+\) concentration of 138–140 mEq/l, sodium acetate, 46 mEq/l and osmolarity 290–298 mOsm/l, thus avoiding rapid changes in the osmotic pressure and volume of body fluids.

The foregoing leads us to conclude that we should turn to a small portable equipment which constantly eliminates water, thus preventing overhydration and leaving only chemical control to the dialysis proper. Ultrafiltration has already been achieved this way by means of a high-ultrafiltration HFK used for several hours on each non-dialysis day. This has enabled us to achieve a considerable but slow moderate water removal, leaving patients to enjoy their meals free from overhydration, leading to the realization of speedy non-symptomatic dialysis.

**CONCLUSION**

It is necessary for non-symptomatic short-time dialysis to achieve (1) increased membrane area, (2) increased blood flow (3) less changes in the osmotic pressure of body fluids and (4) less variation in body weight. In the present study, dialysis of 2M\(^2\) HFK at a blood flow of 300 ml/min with increased osmotic pressure of the dialysate in a recirculating system is performed in a short time without any symptoms. For point (4) an artificial glomerulus is developed for use on non-dialysis days, several hours per day, which prevents water retention and eliminates the need for water restriction.

**References**


