Ten-litre Dialysate Supply System with Adsorbents

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Introduction

The thirty-litre dialysate supply system utilising 500g activated charcoal and 200g alumina was developed three years ago. Since then a number of chronic renal failure patients have been treated with this system and in 36 the effect of the treatment has been precisely evaluated. As previously reported, the clinical results are satisfactory (Maeda et al, 1973). Almost all the home dialysis patients in Japan are using this system and 'non-symptomatic dialysis' in which patients experience few side effects has been achieved.

In order to make the system smaller, a method utilising only ten litres of dialysate with adsorbents was evaluated.

MATERIALS AND METHODS

There are a number of questions associated with thrice-weekly dialysis using a 10L system with a dialysate composition of: sodium 140 mEq/l, potassium 0 mEq/l, chloride 96 mEq/l, calcium 5 mEq/l, magnesium 1 mEq/l and acetate 50 mEq/l. The following factors have to be examined:

1. Is long-term dialysis possible without side effects, when urea removal is limited?
2. Are any toxic substances other than urea unadsorbable with adsorbents?
3. Can electrolytes, especially potassium and calcium, be controlled by 10L dialysate?
4. Is acid-base balance maintained?

We have evaluated clinically the rising rate of urea and input and output of nitrogen compounds when serum urea nitrogen level is kept constant. There is dispute over the toxicity of urea and, in order to examine its adverse effects, a condition in which urea is not eliminated at all is provided by adding urea to 10L dialysate.
Factor 2 is difficult to assess, but careful observation of the patient's clinical status was made and red-cell life span and motor-nerve conduction velocity (MNCV) were measured. Glucose tolerance tests were conducted and bleeding and clotting times were measured as parameters of the toxicity of urea.

BUN, creatinine and uric acid were measured before and after dialysis. Na, K, Cl, PO₄ and Ca were also measured.

The effects of adsorbents were examined by using the ultrafiltrate obtained from the blood by the extracorporeal ultrafiltration method (ECUM), which is widely utilised in Japan (Kobayashi et al, 1972 – Figure 1).

![Diagram showing extra-corporeal ultrafiltration method (ECUM).](image)

In a female patient, age 46, a recirculating system of 10L dialysate with activated charcoal and alumina was used with the addition of 30g of urea to the dialysate. The initial concentration of urea in the dialysate was around 78–96 mg/dl and one week later 40g urea was added to 10L of dialysate, producing a urea nitrogen concentration of 90–123 mg/dl in the dialysate. Her predialysis BUN level was increased to around 150 mg/dl and the post-dialysis was around 140 mg/dl. The levels began to stabilise and show fewer fluctuations, and nitrogen balance for this period was calculated. In an attempt to investigate transference of nitrogen compounds, 1.0g of ¹⁵N-labelled urea was given intravenously to this patient and its incorporation into serum protein examined.

**RESULTS**

The rising concentrations of HCO₃ after dialysis were studied for each concentration of acetate and a value was chosen so that post-dialysis HCO₃ concentrations were 23–25 mEq/l. For the 30L dialysate system, acetate concentrations around 38 mEq/l, ranging between 35 and 45 mEq/l, have already been successful, which makes controlled dialysate concentration possible. In the case of 10L dialysate systems, an acetate concentration of 50 mEq/l is now accepted as a level at which HCO₃ concentration after dialysis may be normalised.
<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Sex</th>
<th>Body weight (kg)</th>
<th>Duration (months)</th>
<th>BUN Predialysis (mg/dl)</th>
<th>Creatinine (mg/dl)</th>
<th>PO₄ (mg/dl)</th>
<th>K (mEq/l)</th>
<th>Ca (mEq/l)</th>
<th>Ht (%)</th>
<th>MNCV</th>
<th>Life span of RBC (days)</th>
<th>GOT (unit)</th>
<th>GPT (unit)</th>
<th>General condition</th>
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<td>48</td>
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<td>108</td>
<td>9.8</td>
<td>7.2</td>
<td>4.5</td>
<td>3.8</td>
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<td>48</td>
<td>28</td>
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<td>51</td>
<td>M</td>
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<td>4</td>
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<td>5.4</td>
<td>4.8</td>
<td>4.2</td>
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<td>5.2</td>
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<tr>
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Potassium concentration in 30L of dialysate is kept around 1.5–2.0 mEq/l which results in 30–60 mEq removal for each dialysis. In the case of 10L of dialysate, there is a total removal of 30–42 mEq. For Japanese of average weight 50 kg, thrice-weekly haemodialysis is conducted without causing hyperkalaemia by this method. Calcium concentration is provided at a concentration of 5 mEq/l; however, since the longest case is only seven months, its effect on bone is not clear and long-term study is required. Five chronic renal failure patients have been treated with 10L dialysate systems and their clinical results at September 1974 are shown in Table I. There are few differences in haematocrit value, MNCV, appetite and well-being between patients treated with the 30L system and those treated with the 10L system over seven months. As previously reported, in spite of the fact that the urea removal with a 30L system is less than with a single-pass system, the BUN level showed little increase and its pre-dialysis level began to decrease after six weeks. With the reduction of the dialysate to 10L, the BUN level increased transiently to a peak of 150 mg/dl, but began to decrease gradually in two months and stabilised at a level of 100 mg/dl. Moreover, as shown in Figure 2, in the fifth patient 30–40g of urea was added in 10L dialysate. In this case the BUN level tended to increase but stabilised at around 150 mg/dl without further elevation. When the removal rate of urea was controlled, blood urea concentration stabilised and even decreased at six/eight weeks.

Since nitrogen balance was adequately maintained, there is a possibility that urea nitrogen was re-utilised. This possibility is emphasised by the addition of urea to the dialysate. When nitrogen balance was calculated, about 12 days of maintained nitrogen balance selected from BUN transition in Figure 2, it was suspected that a significant amount of oral nitrogen was incorporated into amino acid, proteins and faeces. Consequently 2g of $^{15}$N-labelled urea was given intravenously to a fourth and fifth patient. Urea incorporation into serum protein up to 48 hr later was examined. The results are shown in Figure 3 which illustrates a large amount of $^{15}$N incorporation.

Digestive disorders, odour, and bleeding tendency which are characteristic of uraemia were not a serious problem when the BUN was kept at 150 mg/dl and other substances were controlled by adequate dialysis. The glucose tolerance tests for five patients were in the normal range. Although the BUN levels of these patients were maintained at 100–150 mg/dl, they had no nausea and vomiting and they were not clinically more uraemic than other haemodialysis patients. Patients weighing 40–58 kg treated by 10L dialysate with 500g activated charcoal and 200g alumina show little difference from those treated with a 30L dialysate supply system and a single-pass system.

**DISCUSSION**

When chronic haemodialysis is performed with a 10L dialysate supply system with dialysate composition shown above, acid-base balance, water and electrolytes
Figure 2. BUN level of a case treated with 10L dialysate supply system.

Figure 3. Incorporation of $^{15}$N urea in proteins of a patient treated with a 10L dialysate supply system on free diet.
are controlled satisfactorily. For a heavier patient an elevated potassium level is expected, but this problem is solved by giving an ion-exchange resin. When compared with treatment of renal failure by microcapsule artificial kidney (Chang et al, 1972), in terms of electrolyte control, acid-base balance, ultrafiltration and removal of unknown solutes which are not adsorbed by charcoal, the 10L dialysate supply system appears more advantageous. Moreover, when compared with the system utilising urease and zirconium phosphate (Gordon et al, 1968), the 10L dialysate system is more portable and easier to handle. It is reported that urea incorporation into serum protein occurs with a protein-controlled diet (Giordano et al, 1968); however, in our study this phenomenon is demonstrated even with controlled removal of urea and a protein-free diet. This leads up to support urea transference into amino acids and other nitrogen compounds.

CONCLUSION

Five patients, treated for a maximum of seven months, were dialysed with only 10L dialysate without any adverse effects. Although their urea levels are higher than with conventional dialysis, no recognisable disadvantages seem to be caused by the high urea level. In addition, urea incorporation into serum protein is demonstrated with a limited removal of urea and a protein-free diet.

References


Open Discussion

G ORLANDINI (Italy) One of the greatest problems of the regeneration of the dialysis fluid is the correction of pH. What about this?
MAEDA We use 50 mEq/l acetate concentration for dialysate, so we can control the HCO₃ level after dialysis.
C FUCHS (GFR) Have you had any trouble with ammonia breakthrough in heavier patients?
MAEDA We usually use ultraviolet irradiation for the sterilisation of dialysate. We therefore don’t find any ammonia in the dialysate and don’t find high-level ammonia in serum.

O BETTER (Israel) Concerning the question of correcting the pH, just giving one spoonful of bicarbonate is sufficient to correct the bicarbonate level.

MAEDA We don’t use an ion-exchange system to correct acid-base balance, rather a high concentration of acetate.

BETTER Just eating two spoonsful of bicarbonate is sufficient to cover our positive balance of 70 mEq a day of pH.