PART VII

DIALYSIS TECHNIQUES

Chairmen: Ch. Mion
S Shaldon
Long-term Experience of Home Dialysis with Sorbent Regeneration of Dialysate

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Summary

Eleven patients have been treated with a system using sorbent regeneration of dialysate for periods of up to twenty months, with satisfactory rehabilitation and biochemical control. The delay in initiating home dialysis for these patients has been reduced. Although the running costs of sorbent dialysis are higher they are balanced by savings of installation costs for a single-pass system. Acid-base maintenance is improved by increasing the acetate concentration of the initial dialysate prime.

Introduction

Working in London we have become very aware of the disadvantages of using a conventional single-pass system requiring formal installation for regular dialysis at home. Only about 30% of our patients had a spare room immediately suitable for home conversion. For the remainder we had to consider building an extension, using a portable cabin in the garden or even rehousing the whole family before conventional home dialysis could be initiated. Further delays due to the building contractors and limited co-operation from local councils result in clinical frustration (Smith et al, 1969). A permanent installation represents a considerable, inflexible, capital investment which is wasted if the patient is transplanted. The hidden costs of a prolonged stay on hospital dialysis with its increased risk of hepatitis and poorer degree of rehabilitation must also be considered.

The solution to these problems (Wing, 1975) may lie in a portable dialysis
system whose use is under the control of the doctor alone and which does not
depend on co-operation from architects, plumbers and Government administra-
tive departments. The sorbent regeneration system (Redy System Organon
Teknika) offered some prospect of combating these problems (Gordon et al,
1970, 1971). The unique advantage of this system is that the dialysate is re-
generated by passage through a multi-layer cartridge, which combines enzymatic
hydrolysis of urea with ion-exchangers and sorbents. The equipment is therefore
independent of plumbing both for water supply and for drainage and can be
used without prior home adaptation. During the last two years we have carried
out a field trial of this system in order to assess its role in home dialysis in
London. We have also performed biochemical studies on our patients to compare
their pH and biochemical states with those found in patients treated by single-
pass dialysis.

PATIENTS AND METHODS

Of forty-five new patients entering the dialysis programme between October 1974
and March 1976 eleven were chosen for the system using sorbent regeneration of
dialysate (SRD) because of at least one major contraindication to the use of a
single-pass system (SPS). Four of these patients had large families with four or
more children so that there was no room suitable for conversion. Four patients
had expressed a wish for early transplantation. For six patients the cost of home
adaptation would have been more than £2,000. Two patients were awaiting re-
housing for reasons not connected with their treatment, one because of sale of
the house and the other on terminating his military service.

The SRD patients dialysed thrice weekly for a total of eighteen to twenty-one
hours, thus they used three cartridges per week. A Gambro 1 M² disposable
kidney was used three times for reasons of economy. Measurements of pre-
dialysis biochemistry and pH in the SRD group have been compared with those
obtained in a similar group using a single-pass system (SPS) at home. This group
dialysed for eighteen to twenty-one hours per week using a Cambridge propor-
tionating machine and Multipoint 1 M² dialyser. Each value shown is the mean
of between thirty-three and fifty-seven separate pre-dialysis observations, except
for the pH values which are the arithmetic mean of between fifteen and twenty-
one observations. Standard error is shown after the mean.

The particular acetate concentration of each priming solution used by the
SRD patients arose from the reduced quantity of chemical concentrate necessary
to allow for sodium generation by the cartridge. Thus the priming solutions
studied had actual acetate concentrations of 32 mmol/L, 41 mmol/L and
55 mmol/L respectively prior to insertion of the cartridge.

RESULTS

Of the original eleven patients nine are currently on SRD at home, one having
TABLE I. Home Dialysis Using Sorbent Regeneration of Dialysate (SRD) – Description of Patients

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (yr)</th>
<th>Weight (kg)</th>
<th>Sex</th>
<th>Date of starting home dialysis (SRD)*</th>
<th>Reasons against single-pass system (SPS)</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td>Space</td>
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<tr>
<td>1 NH</td>
<td>54</td>
<td>68</td>
<td>M</td>
<td>7.10.74</td>
<td>+</td>
</tr>
<tr>
<td>2 CA</td>
<td>21</td>
<td>55</td>
<td>M</td>
<td>28.10.74</td>
<td>+</td>
</tr>
<tr>
<td>3 MM</td>
<td>37</td>
<td>51</td>
<td>F</td>
<td>18.11.74</td>
<td>+</td>
</tr>
<tr>
<td>4 ML</td>
<td>26</td>
<td>50</td>
<td>F</td>
<td>24.02.75</td>
<td>+</td>
</tr>
<tr>
<td>5 RS</td>
<td>39</td>
<td>69</td>
<td>M</td>
<td>7.03.75</td>
<td>+</td>
</tr>
<tr>
<td>6 DM</td>
<td>21</td>
<td>59</td>
<td>M</td>
<td>14.05.75</td>
<td>+</td>
</tr>
<tr>
<td>7 CB</td>
<td>22</td>
<td>53</td>
<td>F</td>
<td>13.08.75</td>
<td>+</td>
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<tr>
<td>8 BL</td>
<td>44</td>
<td>58</td>
<td>M</td>
<td>15.10.75</td>
<td>+</td>
</tr>
<tr>
<td>9 TW</td>
<td>46</td>
<td>76</td>
<td>M</td>
<td>29.01.76</td>
<td>+</td>
</tr>
<tr>
<td>10 GH</td>
<td>50</td>
<td>81</td>
<td>M</td>
<td>11.02.76</td>
<td>+</td>
</tr>
<tr>
<td>11 DB</td>
<td>41</td>
<td>76</td>
<td>M</td>
<td>31.03.76</td>
<td>+</td>
</tr>
</tbody>
</table>

MEAN 36 yr 63 kg

*Patient 4 has since been transplanted, Patient 7 has been rehoused and now uses a single-pass system.

All other patients are currently being treated by SRD
been transplanted and one who has been rehoused now uses a single-pass system. The mean delay in initiating SRD is markedly reduced compared to that needed for a single-pass installation: 3.7 months compared to 8.3 months (Table I).

**TABLE II. Comparison of Pre-dialysis Biochemistry and pH in Single-pass System (SPS) Patients and Sorbent Regeneration Dialysate (SRD) Patients**

<table>
<thead>
<tr>
<th></th>
<th>Single-pass system (SPS)</th>
<th>Sorbent Regeneration of Dialysate (SRD)</th>
<th>Sorbent Regeneration of Dialysate (SRD)</th>
<th>Sorbent Regeneration of Dialysate (SRD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blood Urea (mmol/L)</strong></td>
<td>22 ± 0.8</td>
<td>25 ± 0.6</td>
<td>26 ± 1.2</td>
<td>25.4 ± 1.0</td>
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<td>+ SEM</td>
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<tr>
<td><strong>Plasma Creatinine (mmol/L)</strong></td>
<td>970 ± 40</td>
<td>1100 ± 30</td>
<td>1083 ± 27</td>
<td>1067 ± 37</td>
</tr>
<tr>
<td>+ SEM</td>
<td></td>
<td></td>
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<tr>
<td><strong>Plasma Sodium (mmol/L)</strong></td>
<td>139 ± 0.9</td>
<td>140 ± 0.5</td>
<td>141 ± 0.5</td>
<td>140.7 ± 0.4</td>
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<tr>
<td>+ SEM</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Plasma Potassium (mmol/L)</strong></td>
<td>4.9 ± 0.1</td>
<td>4.3 ± 0.1</td>
<td>4.3 ± 0.1</td>
<td>4.3 ± 0.1</td>
</tr>
<tr>
<td>+ SEM</td>
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<tr>
<td><strong>Plasma Bicarbonate (mmol/L)</strong></td>
<td>24 ± 0.5</td>
<td>15 ± 0.5</td>
<td>17.4 ± 0.6</td>
<td>19.5 ± 0.5</td>
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<tr>
<td>+ SEM</td>
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<tr>
<td><strong>pH ± SEM</strong></td>
<td>7.40 ± 0.03</td>
<td>7.33 ± 0.05</td>
<td>7.37 ± 0.04</td>
<td>7.38 ± 0.06</td>
</tr>
<tr>
<td><strong>Leucocyte Potassium (mmol/kg cells dry weight)</strong></td>
<td>424 ± 19</td>
<td>364 ± 17</td>
<td>400 ± 24</td>
<td>–</td>
</tr>
<tr>
<td>+ SEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Plasma Calcium (mmol/L)</strong></td>
<td>2.52 ± 0.02</td>
<td>2.37 ± 0.02</td>
<td>2.60 ± 0.03</td>
<td>2.49 ± 0.03</td>
</tr>
<tr>
<td>+ SEM</td>
<td></td>
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<tr>
<td><strong>Plasma Phosphate (mmol/L)</strong></td>
<td>1.75 ± 0.05</td>
<td>1.95 ± 0.1</td>
<td>1.80 ± 0.1</td>
<td>2.06 ± 0.1</td>
</tr>
<tr>
<td>+ SEM</td>
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</tbody>
</table>
SRD patients had levels of urea and creatinine about 15% higher than those on single-pass dialysis, with no major difference in sodium and potassium levels. The use of a dialysate prime in the SRD patients with an acetate concentration of 32 mmol/L was associated with a marked hyperchloremic acidemia which has been much improved by successive increases in the concentration of acetate in the prime. There is no major difference in the current levels of calcium and phosphate between the two groups. Use of a dialysate with a calcium concentration of 2 mmol/L in the SRD 2 group was associated with elevation of plasma calcium levels which have settled with a reduction of the calcium concentration to 1.75 mmol/L (Table II).

DISCUSSION

We attribute the elevation of plasma urea and creatinine levels of the SRD patients to the lower dialysance of these small molecules produced by the lower dialysate flow-rate dictated by the cartridge, 200 ml/min compared to 500 ml/min with the single-pass system. No prominent symptoms of "uraemia" were associated with this elevation and the figures are certainly acceptable, especially in the light of experience with short dialysis schedules and the possible role of urea recycling (Richards, 1975). To allow for the somewhat restricted urea handling capacity of three cartridges per week the SRD patients are officially limited to 60 g of protein per day, although it is unlikely that they observe this restriction strictly. Premature cartridge exhaustion has occurred only rarely, usually after a long interval between dialyses and we have encountered no clinical symptoms attributable to ammonia toxicity.

There is no difference in the levels of plasma sodium in the two groups. The initial dialysate sodium concentration of the SRD patients was 122 mmol/L, and although this level may rise to 150 mmol/L by the end of dialysis this is offset by the sodium lost with ultrafiltration, so that no clinical evidence of sodium retention occurred in these patients. We introduced a conductivity meter as a safeguard for home dialysis to ensure that some, but not double the correct amount of dialysate concentrate was added prior to dialysis. Even quite major variations in the starting sodium concentration may not have serious clinical effects because of the limited size of the dialysate pool.

The SRD patients had slightly lower levels of plasma potassium, probably reflecting the fact that the dialysate is virtually potassium free, due to the high affinity of the cation-exchange layer for this ion. Initially it was our practice to infuse potassium to give a concentration of 1 mmol/L, comparable with single-pass system patients. Because of problems with hyperkalaemia, associated with inadequate acid-base maintenance we have now discontinued this so that the SRD patients dialyse with no potassium added to the dialysate prime or infusate.

The initial dialysate acetate concentration of 32 mmol/L (SRD I) produced a marked hyperchloremic acidemia. The buffer capacity of the SRD system
is affected by the amount of acetate in the prime, together with the acetate infused during dialysis as well as bicarbonate and chloride produced by the cartridge (Better et al, 1970; Pederson & Christiansen, 1976). Increasing the acetate prime to 41 mmol/L, prior to cartridge insertion, lessened the severity of the acidaemia and a further increase to 55 mmol/L produced levels of pH comparable to the patients on single-pass dialysis, although the level of plasma bicarbonate is still significantly reduced. As some of the SRD patients have been using this latter concentration for a comparatively short time it may be that further improvement will be observed on the figures reported here.

During the initial use of SRD we observed hyperkalaemia, occasionally marked, during the development of the acidaemia. Subsequent equilibration in the acidaemic state was associated with levels of plasma potassium within the normal range. It was predicted that the initial hyperkalaemia would be associated with a steady loss of potassium from the body, mainly from the intracellular compartment, and that a new equilibrium would arise across the cell membrane with normal levels of extracellular potassium and reduced levels of intracellular potassium. Studies previously reported from the Renal Laboratory at St Thomas’ Hospital (Patrick & Bradford, 1972) have suggested that measurement of leucocyte potassium may provide a useful index of potassium depletion. It has been shown (Patrick et al, 1972) that patients on single-pass dialysis with good maintenance of acid-base balance, had levels of leucocyte potassium similar to healthy controls. The SRD patients in the acidaemic state showed a significant reduction in their leucocyte potassium content, possibly reflecting whole body potassium depletion. The improvement in the acidaemia produced by increasing the acetate prime to 41 mmol/L was associated with a return of the leucocyte potassium levels towards normal.

There is no major difference in the levels of calcium and phosphate between the SRD 3 and SPS groups. The SRD 1 patients had a marginal reduction in calcium levels, although, because of the associated acidaemia, there may not have been reduced levels of ionised calcium. Because of this slight difference we increased the dialysate calcium concentration to 2 mmol/L in the SRD 2 group. This raised plasma calcium levels but because of the increased displacement of sodium from the cation exchange resin could, theoretically, have reduced the urea capacity of the cartridge. Some patients complained of increased thirst at this time, possibly related to changes in sodium balance although no alteration in mean pre-dialysis plasma sodium levels was demonstrated. This symptom settled with the return to the current dialysate calcium concentration of 1.75 mmol/L. To date, there has been no histological, radiological or clinical evidence of acceleration of the bone disease in the SRD patients, although the time intervals involved are too short to reach any definite conclusions.

CONCLUSION

All of the patients have achieved good rehabilitation with full-time employment
or study or are fulfilling their previous role as housewives. The domestic upheavals of a permanent installation have been avoided. The SRD system can be stored out of sight in a cupboard when not in use. The portable system has been used for travel, to conferences for example, and one of our patients has adapted his caravan in order to use the SRD system on a holiday abroad.

We have managed to avoid much of the frustration and delay of home adaptation by using a system where the only factor determining home transfer is the time needed for patient training, usually comparatively short. Servicing of the units has been performed by our technical staff at the Renal Unit, removing the need for expensive home visits. Although technical faults were infrequent they were dealt with by the patient bringing the unit to the hospital by car, and taking a spare one home. The size of the transplant recipient pool has been increased and the successful transplantation of a patient on home dialysis no longer represents an irretrievable financial loss.

Basic capital costs are about the same (Wing, 1975) although the SRD system costs about £1,000 more a year to run, due, mainly, to the costs of the cartridge required for each dialysis. These increased costs must be set against the price of a home conversion, which may easily be £3,000, together with an extra six to nine months spent on hospital dialysis in the waiting period. A year on hospital dialysis costs approximately £3,000 more than a year spent at home.

Adequate biochemical control was observed in the SRD patients. However, the restriction of a dietary protein to 60 g per day has been resented by some patients.

Initial doubts that acid-base maintenance would be adequate using the SRD system have largely been resolved by successive increases in the acetate concentration of the priming dialysate. The optimal acetate concentration is a matter of ‘trial and error’ as direct extrapolation from the levels used in single-pass dialysis is not possible because of the dynamic aspects of the SRD system.

References

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Open Discussion

CATTELL (London) Given your higher running costs and the difference in installation costs, how long is it going to take before you break even? In other words how long can you afford to keep a patient on home dialysis on the sorbent system, with a higher running cost, before it equates with the more conventional system?

MANSSELL Well, the cost of home conversion is going up every year, but the calculations that we did show that, if your patient is going to be at home for a period up to two years but no longer, there is probably no financial difference between the two systems.

WALLS (Leicester) Most people running home dialysis programmes experience some readmission rate to hospital, either for technical or medical problems. Have you noticed any difference in the readmission rate to your hospital in the patients on sorbent dialysis against those on standard dialysis treatment?

MANSSELL No, I do not think there is any major difference in the number of medical problems occurring in these patients, and technical problems have been fairly infrequent.

DRUKKER (Amsterdam) I would like to ask Dr Mansell if he has seen any difference in bone status between long term SRS patients and patients treated with conventional systems.

Also another comment. I think you save money by using much less concentrate for the SRS and this compensates for the extra cost of the cartridge. Therefore the cost is not very much higher with the SRS than for dialysis with conventional systems.

MANSSELL Yes, as far as the first question goes, the bones have not melted away in the short time that we have had these patients on treatment, but the longest time is 20 months, which in terms of bone disease is too soon to reach any definite conclusions. Nothing dramatic has occurred yet. Our comparative costing of the two systems takes into account the smaller amount of dialysate needed. I must emphasise that the sorbent system is significantly more expensive so that we have used it only for patients with particular contra-indication to a single-pass system.

PARSONS (London) Could you tell us if you measured the blood acetate at the end of a dialysis against 55 mmol acetate? You are getting near the point where there is some work to suggest that this is cardio-depressant; have you measured what is happening at the end of dialysis, and have you noticed hypotension, tachycardia, arrhythmias which one might expect when the acetate is high?
MANSELL The short answer is that we have not measured blood acetate levels. The concentrations that I gave you are those immediately prior to the insertion of the sorbent cartridge and I think that work from Dr Van Doorn suggests that you do get a fall of at least 10 mmol/L in the acetate concentration after the cartridge has interacted with the dialysate.