STUDIES IN CALCIUM METABOLISM IN PATIENTS ON CHRONIC HAEMODIALYSIS

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The long-term nutritional requirements of patients undergoing chronic haemodialysis for terminal renal failure are unknown. The present paper represents our initial studies in this area and is restricted to a consideration of calcium requirements.

It is well-known that the chronic dialysis patient is subjected to the hazards of metastatic calcification on the one hand and demineralisation with osteomalacia on the other (Pendras and Erickson, 1965). Somewhere between these extremes lies the optimum. To define these parameters, the diffusible plasma calcium was first measured.

Arterial blood entering the dialysate or 'venous' blood leaving it was collected anaerobically into vacutainers. pH and pCO$_2$ on the whole blood was immediately measured by the Astrup technique at 37°C. All patients were dialysed using Kii1 kidneys with recirculated dialysate at 37°C. Cuprophane PT 150 membranes were used. Bath calcium concentration was 6.0 mg% unless otherwise indicated. Eleven patients were studied and their duration on dialysis is shown in Table I. Using sealed bags shown in Figures 1 and 2, plasma was transferred

<table>
<thead>
<tr>
<th>Duration on dialysis</th>
<th>Number of patients</th>
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<tbody>
<tr>
<td>&lt; 1 year</td>
<td>3</td>
</tr>
<tr>
<td>1-2 years</td>
<td>2</td>
</tr>
<tr>
<td>&gt; 2 years</td>
<td>6</td>
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Mean duration – 21 months  
Mean age – 39 years  
9 Males – 2 Females

into Cuprophane sausage tubing in the appropriate atmosphere of CO$_2$. The pH and pCO$_2$ of this plasma were measured and an ultrafiltrate prepared anaerobically in a thermostatically controlled centrifuge at 37°C. Finally the pH and pCO$_2$ of the residue in the sac was again measured. Figure 3 shows the pH of the original whole blood sample plotted against the final pH of the residue left inside the membrane. The diagonal line is the line of identity. Figure 4 shows the pCO$_2$ values with again excellent similarity except for the post-dialysis 'venous' values where a sufficiently high CO$_2$ gas concentration was not used. Table II shows the results. It can be seen that irrespective of the pH and pCO$_2$, the diffusible calcium was 60 to 64% of the total calcium and was considerably higher than arterial plasma calcium from normal controls. Plasma protein values were slightly lower in the patients (Table III). The plasma arterial calcium was lower in the patients than the controls.

The net uptake or loss between blood and dialysate was then measured. (Fig. 5). In order
to obtain these points, the dialysate calcium was varied above and below the usual value of 6 mg%. On this figure the venous minus the arterial calcium across the dialyser is plotted on the abscissa. A positive number indicates blood leaving the dialyser has more calcium in it than when it entered and is shown on the right hand side as uptake with the converse on the other side. On the ordinate is shown the arterial blood minus the bath calcium concentrations. When this is a large number the bath calcium is low and calcium passes from blood to dialysate. The diagonal line drawn through the points crosses the Y axis at 4 mg%. Thus with an arterial calcium of 10 mg% and a bath of 6 mg%, no net transfer would be expected to take place and the diffusible calcium would be 60% of the total which is what was found. It is apparent that if the arterial calcium is below normal, then using the same dialysate concentration of 6 mg%, uptake into blood will occur.
TABLE II

Plasma calcium mg\% 

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Diffusible</th>
<th>% Diffusible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls (16)</td>
<td>9.53</td>
<td>4.66</td>
<td>48.8</td>
</tr>
<tr>
<td>Pre-dialysis arterial (11)</td>
<td>8.96</td>
<td>5.75</td>
<td>64.0</td>
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<tr>
<td>Pre-dialysis venous (11)</td>
<td>9.28</td>
<td>5.82</td>
<td>62.8</td>
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<tr>
<td>Post-dialysis arterial (11)</td>
<td>8.97</td>
<td>5.39</td>
<td>60.2</td>
</tr>
<tr>
<td>Post-dialysis venous (11)</td>
<td>9.13</td>
<td>5.67</td>
<td>62.1</td>
</tr>
</tbody>
</table>

Correlation between pH of whole blood and residue

Fig. 3.

Correlation between pCO₂ of whole blood and residue

Fig. 4.

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Figure 6 illustrates this for a subject on dialysis for 2½ years during which time his arterial calcium values have remained normal. Pre- and post-dialysis arterial calcium concentrations do not change indicating no net transfer during dialysis. Note his normal dietary calcium intake. A bone biopsy (Fig. 7) from the iliac crest shows no signs of osteitis fibrosa or osteomalacia.

In contrast this patient (Fig. 8) shows consistently higher post-dialysis values indicating uptake of calcium from dialysate to blood. The reason for his low pre-dialysis calcium levels
is his low dietary intake and, as shown in Figure 9, his iliac crest bone biopsy shows osteitis fibrosa and osteomalacia.

Figure 10 shows serial changes in calcium concentration during a single dialysis in a similar patient. The dialysate calcium was increased to 7.2 mg%. The venous level plateaus as equilibrium with the bath is reached but the arterial level rises progressively. A total of 658 mg of calcium were absorbed.

Six patients had bone biopsies. Two of these had low serum calciums and both showed osteitis fibrosa and osteomalacia. These lesions were not present in the remainder. Calcium balances in four patients are shown in Table IV. Large negative balances tend to occur due to fecal losses. Calculated calcium intakes for all the patients gave a mean value of 500 mg/day as compared to a minimum desirable level of at least 800 mg/day. It is significant that four of the patients had low serum calciums and all of these had intakes of less than 500 mg/day.
Our conclusions are summarised below.

1. Diffusible calcium averages 61% of total calcium in our uraemic patients.
2. Calcium transfer on dialysis depends on (a) arterial level, (b) dialysate level.
3. With dialysate calcium of 6 mg% and normal serum calcium, no net transfer occurs.
4. Calcium depletion is common owing to inadequate intake with malabsorption.
5. Elevation of dialysate calcium although supplying extra calcium does this acutely and could produce metastatic calcification.
6. *Dietary calcium supplementation is indicated.*

**REFERENCE**

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