THE HARD WATER SYNDROME: A POTENTIAL HAZARD DURING REGULAR DIALYSIS TREATMENT

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It is generally accepted that long-term haemodialysis whether preparative for renal transplantation or not should be a safe procedure without interference with the patient’s well-being both during treatment and between haemodialysis. Nevertheless, each haemodialysis remains a potentially hazardous treatment (Grimsrud et al., 1967; Scribner, 1967) and widely divergent patterns of complications and difficulties either from technical, bacteriological or biochemical origin have been described by several authors (Schreiner et al., 1967).

On the other hand, long-term haemodialysis has become a much more safe procedure thanks to increasing experience of the doctors and better training of personnel. Improved equipment with so-called fail-safe devices and training of patients made even unattended home-dialysis a reality. But we all have to be aware that even sophisticated automatic equipment and fail safe devices might fail to be safe.

On November 14, 1967 three chronic patients were on dialysis in our unit. Dialysate under normal conditions containing 3.0 mEq of calcium per litre was distributed from a central static tank supply.

| TABLE I |
|---|---|---|
| **Blood pressure during hard water haemodialysis** |
| **Time** | **Pat. Ho (58)** | **Pat. Ru (51)** | **Pat. He (25)** |
| Start | 120/90 | 130/100 | 135/90 |
| 1.5 hours | 115/90 | 135/110 | 150/110 |
| 3 **,”** | 120/95 | → 160/120 | 140/100 |
| 6 **,”** | 125/95 | 170/125 | 130/90 |
| 7 **,”** | 130/105 | 160/140 | → 160/120 |
| 8 **,”** | → 140/115 | 230/180 | 170/120 |
| 9 **,”** | 155/120 | 180/150 | 165/110 |
| 10 **,”** | 155/125 | 230/170 | 145/100 |
| 11 **,”** | 175/140 | 180/150 | 160/125 |
| 12 **,”** (end) | 195/155 | 155/115 | 175/140 |

Between 3 and 8 hours after initiation of dialysis a marked increase of blood pressure occurred in all three patients despite a significant loss of weight by ultrafiltration (Table I). All three patients complained of headaches and an abnormal warmth sensation and burning of the skin during the second half of dialysis with profuse sweating in two. All were nauseated either during the last few hours or at the end of treatment and vomiting occurred in two. All three patients complained of general malaise, weakness and lethargy. Two became somnolent and had muscular weakness (Table II).

Shortly before the incident the water softening equipment had been moved and reinstalled and it appeared that the electric timers regulating the regeneration of both exchange columns were not readjusted. In this particular case no regeneration at all had occurred after the day
THE HARD WATER SYNDROME

TABLE II
Symptoms and signs during hard water haemodialysis

<table>
<thead>
<tr>
<th></th>
<th>Pat. Ho</th>
<th>Pat. Ru</th>
<th>Pat. He</th>
</tr>
</thead>
<tbody>
<tr>
<td>General malaise</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Headache</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Nausea</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin burning</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Somnolence</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Muscular weakness</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profuse sweating</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vomiting</td>
<td>+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE III
Hard water haemodialysis. Pre- and post-dialysis plasma electrolytes

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>mEq/l</td>
<td>pre</td>
<td>post</td>
<td>pre</td>
<td>post</td>
<td>pre</td>
<td>post</td>
</tr>
<tr>
<td>Na⁺</td>
<td>133</td>
<td>133</td>
<td>131</td>
<td>130</td>
<td>138</td>
<td>131</td>
</tr>
<tr>
<td>K⁺</td>
<td>5.0</td>
<td>4.0</td>
<td>5.5</td>
<td>4.0</td>
<td>5.6</td>
<td>4.7</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td></td>
<td>7.3</td>
<td></td>
<td>7.5</td>
<td></td>
<td>7.6</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td></td>
<td>3.2</td>
<td></td>
<td>3.7</td>
<td></td>
<td>4.0</td>
</tr>
</tbody>
</table>

of reinstallation. Consequently, on November 14 hard water was delivered and used for the preparation of dialysate.

In Table III pre- and post-hard water dialysis plasma electrolytes are presented; sodium and potassium values were well within the usual ranges. Post-dialysis plasma calcium ranged, however, between 7.3 and 7.6 mEq/l and plasma magnesium values were between 3.2 and 4.8 mEq/l.

TABLE IV
Tap water and 'soft' water electrolytes in Amsterdam

<table>
<thead>
<tr>
<th></th>
<th>Tap water mEq/l</th>
<th>Soft water mEq/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>3.5–4.0</td>
<td>9.2–10.2</td>
</tr>
<tr>
<td>K⁺</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>4.0–4.8</td>
<td>0</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>1.1–1.4</td>
<td>0</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>1–3</td>
<td>1–3</td>
</tr>
</tbody>
</table>

In Table IV tap water electrolyte values in our hospital are presented compared with soft water values; in Table V the influence of failure of the water softening process on dialysate electrolyte values is presented compared with normal dialysate electrolyte values in our unit.

High calcium and magnesium values occurring in the hard water dialysate resulted in a positive gradient between dialysate calcium and magnesium and the ionized fractions in the patients' blood resulting in a transfer of these ions from dialysate into the patients.

In Tables VIa, b and c post-dialysis plasma calcium and magnesium values are presented. Hypercalcaemia persisted for at least 36 hours and the two older patients remained symptomatic for 24–36 hours after finishing treatment, complaining of headaches, nausea and lethargy. The third patient recovered within 12 hours.
**TABLE V**

*Influence of hard water on dialysate electrolytes*

<table>
<thead>
<tr>
<th></th>
<th>Dialysis fluid on Nov. 14 mEq/l</th>
<th>Standard dialysate mEq/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>129</td>
<td>132</td>
</tr>
<tr>
<td>K⁺</td>
<td>2.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>6.0–6.6</td>
<td>3.0</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>2.9–3.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>102</td>
<td>102</td>
</tr>
<tr>
<td>CH₃COO⁻</td>
<td>(35)</td>
<td>(35)</td>
</tr>
</tbody>
</table>

Values between (    ) calculated; all other values analyzed.

**TABLE VIa**

*Plasma calcium and magnesium values during first week after hard water haemodialysis*

<table>
<thead>
<tr>
<th>Pat. Ho (58)</th>
<th>Date (1967)</th>
<th>Plasma Ca²⁺ mEq/l</th>
<th>Plasma Mg²⁺ mEq/l</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nov. 14</td>
<td>7.3</td>
<td>3.2</td>
<td>post dialysis</td>
</tr>
<tr>
<td></td>
<td>Nov. 16</td>
<td>6.2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Nov. 17</td>
<td>5.5</td>
<td>—</td>
<td>pre dialysis</td>
</tr>
<tr>
<td></td>
<td>Nov. 21</td>
<td>4.4</td>
<td>2.8</td>
<td>—</td>
</tr>
</tbody>
</table>

**TABLE VIb**

*Plasma calcium and magnesium values during first week after hard water haemodialysis*

<table>
<thead>
<tr>
<th>Pat. Ru (51)</th>
<th>Date (1967)</th>
<th>Plasma Ca²⁺ mEq/l</th>
<th>Plasma Mg²⁺ mEq/l</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nov. 14</td>
<td>7.5</td>
<td>3.7</td>
<td>post dialysis</td>
</tr>
<tr>
<td></td>
<td>Nov. 16</td>
<td>6.2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Nov. 17</td>
<td>5.5</td>
<td>—</td>
<td>pre dialysis</td>
</tr>
<tr>
<td></td>
<td>Nov. 21</td>
<td>4.7</td>
<td>3.2</td>
<td>—</td>
</tr>
</tbody>
</table>

**TABLE VIc**

*Plasma calcium and magnesium values during first week after hard water haemodialysis*

<table>
<thead>
<tr>
<th>Pat. He (25)</th>
<th>Date (1967)</th>
<th>Plasma Ca²⁺ mEq/l</th>
<th>Plasma Mg²⁺ mEq/l</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nov. 14</td>
<td>7.6</td>
<td>4.0</td>
<td>post dialysis</td>
</tr>
<tr>
<td></td>
<td>Nov. 16</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Nov. 17</td>
<td>4.4</td>
<td>—</td>
<td>pre dialysis</td>
</tr>
<tr>
<td></td>
<td>Nov. 21</td>
<td>4.3</td>
<td>3.5</td>
<td>—</td>
</tr>
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</table>
THE HARD WATER SYNDROME

One wonders whether symptoms and signs of the hard water syndrome have to be ascribed to a sudden hypercalcemia or acute hypermagnesaemia or both. Nausea and vomiting, muscular weakness and lethargy were observed by several authors (Brown, 1966; Freeman et al., 1967) and have been attributed by both groups of authors to acute hypercalcemia.

A syndrome caused by pure hypermagnesaemia has been described recently by Govan et al. (1968). They dialedyzed a group of patients suddenly using a dialysis fluid containing 15 mEq of magnesium but otherwise normal. They observed muscular weakness, loss of muscular power, abnormally brisk reflexes, inability to maintain the erect position and ataxia in all of the six patients, and blurring of vision in three. Blood pressure however, was unaffected in five and decreased in one. All patients complained of a feeling of warmth and had a burning sensation to the face. No magnesium plasma values from Govan's patients were available but their plasma magnesium levels must have been significantly higher than in our patients who had been dialyzed against a dialysate magnesium amounting only to 3.0 mEq/l. Hypertension might be induced by sudden hypercalcemia as mentioned by Earle et al. (1966). From their and our own cases, who presented only mild increase of magnesium plasma values, it might be concluded that increase of blood pressure is caused by sudden hypermagnesaemia. The same might be true for the other predominant symptoms and signs of the hard water syndrome, viz. headaches, nausea and vomiting. Muscular weakness and skin burning might be attributed either to hypercalcemia or to hypermagnesaemia or to both.

Finally it has to be emphasized that a significant increase in blood pressure occurring during dialysis, nausea, vomiting and skin burning should raise suspicion of the hard water syndrome. This syndrome should be considered as a dialysis emergency and might be particularly dangerous in patients who are digitalized. These patients might become less infrequent in the nearby future because an increasing number of centres are now accepting patients up to 60 years for regular dialysis treatment and even younger patients might be previously digitalized because of left ventricular failure in the pre-dialysis period.

This syndrome should be recognized swiftly and demands termination of dialysis and immediate blood calcium evaluation in all patients involved.

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REFERENCES