Metabolic Acidosis in Burns

M. J. T. PEASTON,* M.B., PH.D., M.R.C.P.GLASG.

Though there is an awareness that metabolic acidosis may complicate burns, there is a remarkable paucity of quantitative information on the subject. A number of authoritative reviews on the early management of burns make no mention of metabolic acidosis as a therapeutic problem (Colebrook, 1951; Hay and Cronin, 1954; Wilkinson, 1957; Bocanegra et al., 1966; Barclay, 1967; Lancet, 1967), even though alkali therapy is often advocated. Acidosis is not mentioned among the causes of mortality from burns in reviews which quote up to 24 pre-disposing factors (Rush, 1953; Winterscheid and Merendino, 1960; Phillips and Cope, 1962; Hockmuth and Ziffling, 1963; Birke et al., 1964; Feller and Hendrix, 1964). There is no literature presenting acid-base studies obtained with reliable modern electrodes for measuring arterial pH and PCO₂.

The present study was undertaken in a regional burns unit to investigate the acid-base status of patients during the early post-burn period, and to study the relation between severity of acid-base disturbance and extent of the burn.

Patients

Fourteen consecutive unselected patients admitted to a regional burns unit with burns of more than 15% of the total body surface area were studied. Their ages ranged from 17 to 71 years, and the group includes seven male and seven female subjects (Table I). The severity of burn was assessed in terms of total extent and of partial and full skin thickness involvement. The distinction between partial and full skin thickness was made on clinical grounds, and the percentage of each degree of burn related to the total surface area calculated from standard tables relating surface area to height and body weight. Total extent of burn varied from 18 to 70% of the surface area, with ranges of 4 to 55% for partial skin thickness and of 3 to 45% for full skin thickness involvement.

Four of the patients died, all with 35% or more of full skin thickness burns. Similarly all the patients with more than 40% of total surface area burned failed to survive except for one patient (Case 2) in whom the large surface area involved was predominantly by partial skin thickness burn.

Methods

Acid-base measurements were made on arterial blood samples obtained by intermittent femoral puncture. Arterial pH was measured on an Astrup pH electrode (Radiometer, Copenhagen), and arterial PCO₂ on a Severinghaus PCO₂ electrode (Severinghaus and Bradley, 1958). The severity of acidosis was expressed in terms of the base deficit (Sigggaard Andersen et al., 1960), obtained by interpolation from the Sigggaard Andersen (1962)
Results

Twelve of the 14 patients had a base deficit at some stage after thermal injury, and in seven of these the metabolic acidosis was maximal on admission and in three others within 24 hours (Table II). In four cases with a base deficit of less than −4 no sodium bicarbonate was administered. With more serious degrees of acidosis the bicarbonate requirement was variable, as is well exemplified by two patients (Cases 2 and 12) in whom acidosis of comparable severity was in one instance corrected by 400 mEq given over 24 hours, while in the other 2,750 mEq was required over a period of 11 days.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Total Burned (%)</th>
<th>Maximum Base Deficit (mEq)</th>
<th>Time of Maximum Base Deficit</th>
<th>Lowest pH</th>
<th>Lowest Pco,</th>
<th>Total NaHCO3 Given (mEq)</th>
<th>Time Over which 14 NaHCO3 Given</th>
<th>Total Mean</th>
<th>Time Over which 14 NaHCO3 Given</th>
<th>Total Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30 - 2</td>
<td>On admission 7-48</td>
<td>26</td>
<td>14</td>
<td>2,750</td>
<td>11 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>65 - 15</td>
<td>On admission 7-40</td>
<td>14</td>
<td>27</td>
<td>150</td>
<td>4 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>19 - 4</td>
<td>On admission 7-40</td>
<td>14</td>
<td>27</td>
<td>150</td>
<td>4 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>50 - 6</td>
<td>24 hours 7-24</td>
<td>20</td>
<td>90</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>40 - 10</td>
<td>On admission 7-42</td>
<td>191</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>30 - 3</td>
<td>24 hours 7-45</td>
<td>26</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>40 - 8</td>
<td>24 hours 7-52</td>
<td>27</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>35 - 5</td>
<td>4 days 7-43</td>
<td>29</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>20 - 11</td>
<td>On admission 7-42</td>
<td>25</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>20 - 0</td>
<td>On admission 7-42</td>
<td>25</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>70 - 17</td>
<td>On admission 7-46</td>
<td>27</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>33 - 7</td>
<td>24 hours 7-52</td>
<td>27</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>40 - 6</td>
<td>24 hours 7-52</td>
<td>27</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>30 - 2</td>
<td>On admission 7-48</td>
<td>26</td>
<td>14</td>
<td>2,750</td>
<td>11 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1,100</td>
<td>5,100</td>
<td>31 days</td>
<td>164/day</td>
<td>3-9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results of external balance studies on the eight patients to whom they were applied are summarized in Table III. These showed a mean sodium retention of 48 mEq/day and chloride retention of 21 mEq/day. These results do not indicate an increase of total body chloride relative to sodium.

**Results**

Twelve of the 14 patients had a base deficit at some stage after thermal injury, and in seven of these the metabolic acidosis was maximal on admission and in three others within 24 hours (Table II). In four cases with a base deficit of less than −4 no sodium bicarbonate was administered. With more serious degrees of acidosis the bicarbonate requirement was variable, as is well exemplified by two patients (Cases 2 and 12) in whom acidosis of comparable severity was in one instance corrected by 400 mEq given over 24 hours, while in the other 2,750 mEq was required over a period of 11 days.

**Table II.** Degree of Maximum Metabolic Acidosis in 14 Patients

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Total Burned (%)</th>
<th>Maximum Base Deficit (mEq)</th>
<th>Time of Maximum Base Deficit</th>
<th>Lowest pH</th>
<th>Lowest Pco₂</th>
<th>Total NaHCO₃ Given (mEq)</th>
<th>Time Over which 14 NaHCO₃ Given</th>
<th>Total Mean</th>
<th>Time Over which 14 NaHCO₃ Given</th>
<th>Total Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30 - 2</td>
<td>On admission 7-48</td>
<td>26</td>
<td>14</td>
<td>2,750</td>
<td>11 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>65 - 15</td>
<td>On admission 7-40</td>
<td>14</td>
<td>27</td>
<td>150</td>
<td>4 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>19 - 4</td>
<td>On admission 7-40</td>
<td>14</td>
<td>27</td>
<td>150</td>
<td>4 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>50 - 6</td>
<td>24 hours 7-24</td>
<td>20</td>
<td>90</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>40 - 10</td>
<td>On admission 7-42</td>
<td>191</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>30 - 3</td>
<td>24 hours 7-45</td>
<td>26</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>40 - 8</td>
<td>24 hours 7-52</td>
<td>27</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>35 - 5</td>
<td>4 days 7-43</td>
<td>29</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>20 - 11</td>
<td>On admission 7-42</td>
<td>25</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>20 - 0</td>
<td>On admission 7-42</td>
<td>25</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>70 - 17</td>
<td>On admission 7-46</td>
<td>27</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>33 - 7</td>
<td>24 hours 7-52</td>
<td>27</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>40 - 6</td>
<td>24 hours 7-52</td>
<td>27</td>
<td>7</td>
<td>500</td>
<td>2 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>30 - 2</td>
<td>On admission 7-48</td>
<td>26</td>
<td>14</td>
<td>2,750</td>
<td>11 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1,100</td>
<td>5,100</td>
<td>31 days</td>
<td>164/day</td>
<td>3-9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The relation between acidosis and extent and depth of the burn was investigated by plotting the maximum base deficit in each patient against burned surface area. There was no close relation between maximum acidosis and either partial skin thickness or full skin thickness burn (Table II). When, however, maximum base deficit was related to the total surface area burned there was a definite relation between the two (see Chart). The more extensive the burn the greater the degree of maximum base deficit in each patient. Above 30% of total surface area this relation was linear.

**Table III.** External Balance Data on Eight Burned Patients

<table>
<thead>
<tr>
<th>No. of Cases</th>
<th>Duration of Burns (days)</th>
<th>Cal. Mean Intake</th>
<th>Na</th>
<th>K</th>
<th>Cl</th>
<th>N₄</th>
<th>H₂O</th>
<th>Mean Output</th>
<th>Mean Uncorrected Balance</th>
<th>Mean Corrected Balance</th>
<th>Loss of Lean Muscle Mass (g/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>5-6</td>
<td>4,132</td>
<td>6:15</td>
<td>363</td>
<td>139</td>
<td>315</td>
<td>19-2</td>
<td>3-97</td>
<td>190 97 188</td>
<td>21-03</td>
<td>2-18 173 42 127 -1-03 0-18 48 -39 21 -6-23 127</td>
</tr>
</tbody>
</table>

The limited study reported here shows clearly that acidosis following thermal injury is common, and is most pronounced on admission. The acidosis is usually compensated by respiratory alkalosis. Though there is no close correlation between the maximum base deficit in each patient and the extent of partial or full skin thickness burn, there is a definite relation between the severity of acidosis and the total body surface area burned. When the total extent of burn exceeded 30% of the surface area acidosis became a progressively more serious problem the greater the extent of burn. The acidosis observed could not be ascribed to saline therapy exacerbating pre-existing
hyperchloremia. Though the mean balance data on eight of the patients show chloride retention, this is less than the retention of sodium or loss of potassium. The observations on electrolyte and nitrogen balance reflect the metabolic response to thermal injury rather than change in the acid–base state.

The therapeutic implications of this study are clear. In acute severe illnesses metabolic acidosis commonly predisposes to acute renal failure (Peaston, 1967). Renal failure in severe burns may be due to uncorrected acidosis; in some series it is quoted as the fourth most common cause of death, responsible for 9% of all fatalities (Phillips and Cope, 1962), while in other series it is said to be the second commonest fatal complication (Hockmuth and Ziffren, 1963). With better methods of fluid replacement and treatment of shock, and with improved techniques of surgical care and prevention of secondary infection in the burn itself, the proper management of acid–base disturbances assumes a role of even greater importance. I agree with Arzt (1960) that in burns "acute renal failure does not occur unless there is gross neglect in treatment." It is suggested that the quantitative estimation of metabolic acidosis and its early correction with sodium bicarbonate is an important measure in preventing renal failure in burns, and is more likely to preserve a healthy milieu interior during the critical early period after thermal injury. In view of the small number of patients with extensive burns studied in this series it is suggested that further observations be made in severe burns to confirm the findings reported.

Summary

The acid–base state has been studied by means of serial arterial pH and PCO₂ measurements in 14 patients admitted to a regional burns unit. Metabolic acidosis was a common finding, and in the majority of patients was maximal on or shortly after admission. The maximum degree of acidosis in each patient expressed in terms of the base deficit was found to correlate closely with the total extent of body surface area burned, though there was no close relation between maximum acidosis and either partial or full skin thickness involvement. The severe degrees of base deficit observed were usually compensated by respiratory alkalosis. Above 30% of surface area burned the severity of acidosis increased linearly with the extent of the burn. The therapeutic implications are discussed.

I should like to thank Mr. D. Masels and Mr. A. H. M. Littlewood for their kind permission to study their patients admitted to the Regional Burns Unit at Whiston Hospital and for their constant interest and assistance.

References